❶•❶ Relative masses of atoms and molecules

MCQs

01-1-M-01

07ZZ01-1-M-01

A relative atomic mass of Fe = (54 × 0.058) + (56 × 0.916) + (57 × 0.022) + (58 × 0.004)

= 55.9 (ans)

01-1-M-02

07ZZ01-1-M-02

A ratio of ^{12}C to ^{13}C = (12 × 0.8) + (13 × 0.2) = 12.2; hence ratio = 0.8:0.2 = 4:1 (ans)

01-1-M-03

07ZZ01-1-M-03

D peak at 15 corresponds to CH_3^+

peak at 29 corresponds to $CH_3CH_2^+$

peak at 31 corresponds to CH_2OH^+

peak at 45 corresponds to $CH_2CH_2OH^+$

peak at 60 corresponds to $CH_3CH_2CH_2OH^+$

pattern corresponds to that of $CH_3CH_2CH_2OH$ only (ans)

01-1-M-04

07ZZ01-1-M-04

A $^{55}Z^{55}Z^{55}Z : {}^{55}Z\,^{55}Z\,^{57}Z : {}^{55}Z\,^{57}Z^{57}Z : {}^{57}Z^{57}Z^{57}Z$

165 : 167 : 169 : 171

$x = 3 \times 2 \times 2 \times 1 = 12$

for $^{55}Z\,^{55}Z\,^{57}Z$, $^{55}Z^{57}Z^{55}Z$ and $^{57}Z^{55}Z\,^{55}Z$

$y = 3 \times 2 \times 1 \times 1 = 6$

for $^{55}Z\,^{57}Z^{57}Z$, $^{57}Z\,^{55}Z^{57}Z$ and $^{57}Z\,^{57}Z^{55}Z$

(ans)

01-1-M-05

07ZZ01-1-M-05

C $^{16}O^+$, $^{18}O^+$, $^{16}O^{16}O^+$, $^{16}O^{18}O^+$, $^{18}O^{18}O^+$

peaks: 16, 18, 32, 34, 36

(ans)

01-1-M-06

07ZZ01-1-M-06

B percentage by mass of $^{35}Cl_2$ in the mixture

$$= \frac{(0.4 \times 70) + (0.6 \times 74)}{4} = \frac{72.4}{4}$$

= 18.1g (ans)

01-1-M-07

D M_r of Na_2CO_3 = (23×2)+(12×1)+(16×3) = 106

% by mass of Na = 46 ÷ 106 = 43.4

M_r of Na*Cl* = (23×1)+(35.5×1) = 58.5

% by mass of Na = 23 ÷ 58.5 = 39.3

M_r of NaOH = (23×1)+(16×1)+(1×1) = 40

% by mass of Na = 23 ÷ 40 = 57.5

M_r of Na_2O = (23×2)+(16×1) = 62

% by mass of Na = 46 ÷ 62 = 74.2 (ans)

01-2-M-05

07ZZ01-2-M-05

A no. of electrons to be removed

$= 1.0 \times 10^{-6} \times L$

$= 1.0 \times 10^{-6} \times 6.02 \times 10^{23}$ (ans)

01-2-M-06

07ZZ01-2-M-06

B M_r of bromine = 159.8

no. of bromine atoms present

$$= 2 \times \left(\frac{0.004 \times 10^{-3}}{159.8} \right) \times 6.02 \times 10^{23}$$

$= 3.00 \times 10^{16}$ (ans)

Questions – 1.2

01-2-Q-01

(a) (i) to ensure all of the water of crystallisation had been driven off or to be at constant mass

(ii) mass of $ZnSO_4 = 76.34 - 74.25 = 2.09$ g

M_r $ZnSO_4 = 65.4 + 32.1 + (4 \times 16.0) = 161.5$

$$n(ZnSO_4) = \frac{2.09}{161.5} = 0.01294 = 1.29 \times 10^{-2}$$

$ZnSO_4 = 161$ gives 1.30×10^{-2}

(iii) mass of H_2O driven off $= 77.97 - 76.34$

$= 1.63$ g

$n(H_2O) = 1.63 \div 18 = 0.0905$

$= 9.1 \times 10^{-2}$

(iv) 1.29×10^{-2} mol $ZnSO_4$ are combined with 9.1×10^{-2} mol H_2O

1 mol $ZnSO_4$ is combined with $\dfrac{9.1 \times 10^{-2}}{1.29 \times 10^{-2}}$

$= 7.054 \equiv 7$ mol H_2O

(answer must be expressed as a whole number)

(b) (i) $n(Zn) = n\ (CH_3CO_2)_2Zn.2H_2O$

$n(Zn) = 0.015 \div 65.4$

$= 2.290 \times 10^{-4}$

$= 2.29 \times 10^{-4}$

mass of crystals $= 2.29 \times 10^{-4} \times 219.4$

$= 0.0502655$ g

$= 0.05$ g $= 50$ mg

(ii) concentration of $(CH_3CO_2)_2Zn.2H_2O$

$= (2.29 \times 10^{-4}) \div 0.005 = 0.0458$

$= 4.58 \times 10^{-2}$ mol dm^{-3}

Questions – 1.3

01-3-Q-01

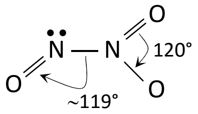
07ZZ01-3-Q-01

(a)

	N	O
% by mass	36.8	63.2
No. of mole	2.63	3.95
Simplest ratio	2	3

Molecular formula of A = N_2O_3

(b)



(c) m/e = 30 $[NO]^+$; m/e = 46 $[NO_2]^+$; m/e = 60 $[N_2O_2]^+$

(d) $N_2O_3 \rightarrow NO_2 + NO$

No. of moles of $N_2O_3 = \frac{2}{76}$

No. of moles of gases formed $= \frac{4}{76}$

$$PV = nRT,\ P = \frac{\left(\frac{4}{76}\times 8.314\times 313\right)}{0.2}\times 10^{-3}$$

$$= 6.84\times 10^{5}\text{ Pa}$$

(e) Ideal gas behaviour. Not valid because under low temperature and high pressure, there are significant intermolecular attractions.

(ans)

01-3-Q-02

07ZZ01-3-Q-02

(i)

	Ca	Si	O
% by mass	34.2	24.5	41.3
No. of mole	0.853	0.872	2.581
Simplest ratio	1	1	3

Empirical formula = $CaSiO_3$

(ii) $Ca_3(PO_4)_2 + 5C + 3SiO_2 \rightarrow 2P + 3CaSiO_3 + 5C$

(iii) no. of moles of P $= \frac{5.3}{31} = 0.0171$ mol

no. of moles of $Ca_3(PO_4)_2 = \frac{1}{2}\times 0.0171$

$= 0.0855$ mol

mass of $Ca_3(PO_4)_2 = 0.0855\times(3\times 40 + 2\times 31 + 8\times 16) = 26.5$ g

% by mass $= \frac{26.5}{30}\times 100 = 88.3\%$

(ans)

01-3-Q-03

07ZZ01-3-Q-03

(i)

m/e	Molecular ion	Relative intensities
172	$CH_2{}^{79}Br_2{}^+$	1
174	$CH_2{}^{79}Br{}^{81}Br^+$	$2x$
176	$CH_2{}^{81}Br_2{}^+$	x^2

(ii) using the peaks at m/e = 170 and 174.

Solving, $x^2 = \frac{4}{9}$

$x = \frac{2}{3}$

(iii) relative atomic mass $= \frac{3}{5}(79) + \frac{2}{5}(81)$

$= 79.8$

(ans)

01-3-Q-04

(a) The total number of protons and neutrons in the nucleus of an atom. [1]

(b) (i) Mass of an atom or isotope [1]
relative to 1/12 the mass of an atom of carbon–12. [1]

(ii) ${}^{79}Br$ ${}^{81}Br$
$78.92x$ $80.92(100-x)$ where x is % abundance of ${}^{79}Br$

$\Rightarrow \frac{78.92x + 80.92(100-x)}{100} = 79.9$ [1]

$\Rightarrow x = 51$ [1]

Hence ${}^{79}Br : {}^{81}Br = 51 : 49$ [1]

(c)

$$\begin{array}{cc} \text{A} & \text{Br} \\ \dfrac{4.31}{A_r} & \dfrac{95.69}{79.9} \end{array} \Rightarrow 1:3$$

$$\Rightarrow \frac{95.69 \div 79.9}{4.31 \div A_r} = 3$$ [1]

$$\Rightarrow A_r = \frac{3 \times 4.31 \times 79.9}{95.69} = 10.796$$ [1]

$= 10.8$ to 3 s.f. [1]

(d) (i) Mg: bright / white light / flame OR white solid / smoke [1]

$Mg + ½O_2 \rightarrow MgO$ [1]

S: blue flame OR white / steamy fumes OR yellow solid disappears [1]

$S + O_2 \rightarrow SO_2$ [1]

(ii) $Al_2O_3 + 2NaOH + 7H_2O \rightarrow 2NaAl(OH)_4(H_2O)_2$ OR

$Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2NaAl(OH)_4$ OR

$Al_2O_3 + 2NaOH \rightarrow 2NaAlO_2 + H_2O$ OR

$Al_2O_3 + 2OH^- + 7H_2O \rightarrow 2[Al(OH)_4(H_2O)_2]^-$ OR

$Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2[Al(OH)_4]^-$ OR

$Al_2O_3 + 2OH^- \rightarrow 2AlO_2^- + H_2O$ [1]

$Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$ [1]

(e) shape of PCl_5 is trigonal bipyramidal. [1]

bond angles in PCl_5 is 120° and 90°. [1]

❶•❹ Reacting masses and volumes (of solutions and gases)

MCQs

01-4-M-01

07ZZ01-4-M-01

B $CaMg(CO_3)_2 + 4HCl \rightarrow CaCl_2 + MgCl_2 + 2CO_2 + 2H_2O$

no. of moles of $CaMg(CO_3)_2 = \dfrac{2.00}{M_r}$

$$= \frac{2.00}{184.3} = 0.01085 \text{ mol}$$

no. of moles of $CO_2 = \dfrac{0.45}{M_r} = \dfrac{0.45}{44}$

$= 0.01023$ mol.

Since 1 mol of $CaMg(CO_3)_2$ produces 2 mol of CO_2, the expected no. of moles of CO_2 is

$= 0.01085 \times 2 = 0.0217$ mol

percentage purity of the sample

$$= \left(\frac{0.01023}{0.0217}\right) \times 100 = 47.1\% \quad \text{(ans)}$$

01-4-M-02

07ZZ01-4-M-02

B no. of moles of hydrogen $= \dfrac{0.01}{22.4}$

$= 0.000446$ mol

$2H_2 + O_2 \rightarrow 2H_2O$

no. of moles of oxygen reacted

$$= \frac{0.000446}{2} = 0.000223 \text{ mol}$$

maximum theoretical decrease in volume

$= (0.000446 + 0.000223) \times 22.4$

$= 15\ cm^3$ (ans)

Questions – 1.4

01-4-Q-01 [HC]

(a) Arsenic can be oxidized to arsenic(V) acid, H_3AsO_4, by dilute nitric acid which itself is reduced to NO_2. Arsenic(V) acid oxidizes I^- to I_2 and is itself reduced to H_3AsO_4.

(i) Write balanced equations for the reactions above.

(ii) The amount of I_2 can be estimated by titration against a standard thiosulfate solution. When 0.1058 g of a sample containing arsenic was subjected to the above reactions, the iodine liberated required 28.70 cm^3 of 0.0198 mol dm^{-3} solution of sodium thiosulfate in the final titration. What is the percentage of arsenic in the sample? (Given $2S_2O_3^{2-}:I_2$)

(b) On reacting potassium chlorate(VII), $KClO_4$, with fluorosulfonic acid, FSO_3H, a gas ***X*** was evolved.

(i) 0.245 g of ***X*** was found to occupy 108 cm^3 at 20°C and at a pressure of 5.20×10^4 Pa. Calculate the relative molecular mass of ***X***.

(ii) The mass spectrum of ***X*** shows among other peak values at m/e ratio of 16, 19, 35, 37 and the molecular ion peaks at 102 and 104. Suggest the molecular formula of ***X***. [*supplementary topic*]

(iii) Would you expect ***X*** to be an ideal gas? Give your reasoning.

01-4-Q-02

[*Examined in* 2012]

Carbon dioxide, CO_2, makes up about 0.040 % of the Earth's atmosphere. It is produced by animal respiration and by the combustion of fossil fuels.

In animal respiration, oxygen reacts with a carbohydrate such as glucose to give water, carbon dioxide and energy.

The typical daily food requirement of a human can be considered to be the equivalent of 1.20 kg of glucose, $C_6H_{12}O_6$.

You should express all of your numerical answers in this question to <u>three</u> significant figures.

(a) (i) Construct a balanced equation for the complete oxidation of glucose.

(ii) Use your equation to calculate the amount, in moles, of CO_2 produced by one person in one day from 1.20 kg of glucose.

(iii) On the day on which this question was written, the World population was estimated to be 6.82×10^9.

Calculate the total mass of CO_2 produced by this number of people in one day. Give your answer in tonnes. [1 tonne = 1.00×10^6 g] [5]

(b) When fossil fuels are burned in order to give energy, carbon dioxide and water are also produced.

The hydrocarbon octane, C_8H_{18}, can be used to represent the fuel burned in motor cars. A typical fuel-efficient motor car uses about 4.00 dm^3 of fuel to travel 100 km.

(i) Construct a balanced equation for the complete combustion of octane.

(ii) The density of octane is 0.700 gcm^{-3}. Calculate the amount, in moles, of octane present in 4.00 dm^3 of octane.

(iii) Calculate the mass of CO_2 produced when the fuel-efficient car is driven for a distance of 100 km. [5]

(c) Calculate how many kilometres the same fuel-efficient car would have to travel in order to produce as much CO_2 as is produced by the respiration of 6.82×10^9 people during one day. Use your answer to (a)(iii). [2]

(d) Carbon dioxide is one of a number of gases that are responsible for global warming. When fossil fuels such as octane are burned in a car engine, other atmospheric pollutants are also produced.

Give the formula of one atmospheric pollutant that may be produced in a car engine, other than CO_2, and state how this pollutant damages the environment. [2]

[Total: 14]

(ii) Copper is a transition element as its d orbital electrons are able to delocalise within the metal lattice. In metallic substances, the more electrons shared between nuclei, the stronger the metal. Therefore copper has stronger metallic bonds which require more energy to break as compared to sodium.

(iii) Vaporization involves the breaking of ionic bonds present in sodium chloride. These are easier to break as compared to the stronger metallic bonds present in a transition element like copper. (ans)

05-1-Q-28

(a) Standard enthalpy change of combustion is the enthalpy change when 1 mol of a substance is burnt in an excess of oxygen/air under standard conditions [1] or is completely combusted under standard conditions. [1]

(b) (i) $m = \frac{pVM_r}{\text{RT}} = \frac{1.01\times10^5\times125\times10^{-6}\times44}{8.31\times293}$ g [1]

$= 0.228147345$ g

$= 0.23$ g [1]

(ii) heat released $= mc\Delta T$

$= 200 \times 4.18 \times 13.8$ J [1]

$= 11536.8$ J $= 11.5$ kJ [1]

(iii) 0.23 g of propane produce 11.5 kJ

44 g of propane produce $\frac{11.5\times44}{0.23}$ kJ

$= 2200$ kJ mol^{-1} [1]

05-1-Q-29

(a) An increase in temperature will lead to an increase in entropy, as the molecular motion increases, leading to greater disorder in the system. (ans)

(b) A change in phase will affect the entropy of a system. In the solid phase, the entropy is the lowest as the solid particles vibrate about a fixed position. In the liquid state, entropy is higher as the liquid particles are able to move about slightly. In the gaseous states, entropy is highest as the gas particles can move freely in all directions, leading to greater disorder. (ans)

(c) An increase in the number of particles will increase the entropy of a system as there is greater disorder, especially in a gaseous system. (ans)

(d) The mixing of particles will increase entropy as there will be greater disorder. (ans)

05-1-Q-30

(a) (i) $K_{sp} = [Ag^+]\,[Br^-]$

(ii) $K_{sp} = (7.1 \times 10\text{-}7)(7.1 \times 10\text{-}7)$

$= 5.0 \times 10^{-13}$ mol^2 dm^{-6}

(b) (i) $\Delta G^\theta_{ppt} = 2.303\,RT \log K_{sp}$

$= 2.303 \times 8.31 \times 298 \times \log(2.0 \times 10^{-10})$

$= -55314.2$ J mol^{-1}

$= -55.3$ kJ mol^{-1}

(ii) $\Delta G^\theta_{ppt} = \Delta H^\theta - \text{T}\Delta S^\theta_{ppt}$

$-55.3 = -66.0 - 298\Delta S^\theta_{ppt}$

$\Delta S^\theta_{ppt} = \frac{-55.3+66.0}{-298}$

$= -0.0359$ kJ mol^{-1}

$= -35.9$ J mol^{-1}

(iii) The negative sign indicates a decrease in the degree of randomness. Since the Ag^+ ions and Cl^- ions dissolved in water form solid $AgCl$, there is now increased order so entropy change is negative.

(c) $\Delta G^\theta_{ppt} = 2.303\,RT \log K_{sp}$

$= 2.303 \times 8.31 \times 298 \times \log(1.006)$

$= 14.8$ J mol^{-1}

AgF is not soluble in water because ΔG^θ_{ppt} is positive. This means that the reaction of AgF dissolving in water is not spontaneous. Hence, AgF will not dissolve in water at 298 K.

05-1-M-31

07ZZ05-1-M-31

A The value of lattice energy is affected by the size and charge of ions. Magnesium and lithium are almost similar in size, but the former has a higher charge of +2. The strength of the ionic bond increases as the charge of the ion increases, leading to a larger value of lattice energy. (ans)

05-1-M-32

07ZZ05-1-M-32

A 2(enthalpy change of formation of $HN_3(l)$)

$= -187.8 + 894 - 2(90.3)$

enthalpy change of formation of $HN_3(l)$

$= 263$ kJ mol^{-1} (ans)

05-1-M-33

07ZZ05-1-M-33

B Equation:

$CH_3OH + \frac{3}{2}O_2 \rightarrow CO_2 + 2H_2O$

enthalpy change of combustion of methanol

$= 2(-286) - 394 + 239$

$= -727$ kJ mol^{-1} (ans)

05-1-M-34

07ZZ05-1-M-34

B Enthalpy change of formation of tetrachloroethene oxygen

$= 52.3 + 4(-92.3) - 878.5 - 4(-285.8)$

$= -52.2$ kJ mol^{-1} (ans)

05-1-M-35

B Specific heat capacity of water = 4.18 J/g°C

Amount of heat gained by water $= mc\Delta T$

$= 100 \times 4.18 \times (53 - 20)$

$= 13794$ J (ans)

05-1-M-36

B When a gas is generation from liquid reactants, there is an increase in the number of particles in a system, hence the entropy is positive.

Decompression of a gas decreases the mixing of particles, hence entropy is negative

Freezing of a liquid reduces the randomness of the system, hence entropy is negative

Condensation of a gas reduces the randomness of the system, hence entropy is negative

05-1-M-37

C The reaction must have a positive enthalpy change because it absorbs energy from the surroundings to create the cold effect to relieve pain.

In the reaction, we can see that the ammonium nitrate is being dissolved in the water. This increases randomness of particles, so the entropy change should be positive as well.

Since the reaction is spontaneous as described in the question, ΔG will be negative.

05-1-M-38

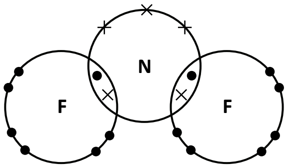
C Structure of N_2F_4 is $F_2N{-}NF_2$

During decomposition, the N–N bond is broken to form NF2:

$$N_2F_4 \xrightarrow{heat} 2NF_2$$

From the Data Booklet, the breaking of N–N bond requires +160 kJ mol^{-1} of energy.

The shape of the NF_2 molecule is shown below. It has a bent geometry:



06-1-M-10

07ZZ06-1-M-10

B No. of moles of $NaBrO_3 = \left(\frac{20}{1000}\right) \times 0.02$

$= 0.0004$

No. of moles of $NH_2OH = \left(\frac{80}{1000}\right) \times 0.01$

$= 0.0008$

$1\ NaBrO_3 \equiv 2NH_2OH$

No. of electrons transferred $= 3$

Half equation: $NH_2OH \rightarrow NO + 3H^+ + 3e$ (ans)

06-1-M-11

A $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$

$N^{-3} \rightarrow N^{+2}$

$3NO_2 + H_2O \rightarrow 2HNO_3 + NO$

$N^{+4} \rightarrow N^{+5} + N^{+2}$

$2NO + O_2 \rightarrow 2NO_2$

$N^{+2} \rightarrow N^{+4}$

$4NH_3 + 6NO \rightarrow 5N_2 + 6H_2O$

$N^{-3} + N^{+2} \rightarrow N^0$

06-1-M-12

C $2KCl + H_2SO_4 \rightarrow K_2SO_4 + 2HCl$

$S^{+6} \rightarrow S^{+6}$

$2KBr + 2H_2SO_4 \rightarrow K_2SO_4 + SO_2 + Br_2 + 2H_2O$

$S^{+6} \rightarrow S^{+6} + S^{+4}$

$8KI + 5H_2SO_4 \rightarrow 4K_2SO_4 + H_2S + 4I_2 + 4H_2O$

$S^{+6} \rightarrow S^{+6} + S^{-2}$

Questions – 6.1

06-1-Q-01

07ZZ06-1-Q-01

(a) $2NO_2 + H_2O \rightarrow HNO_2 + NO_3^- + H^+$

Yes, the reaction will occur.

The reduction reaction is $NO_2 + H^+ + e \rightarrow HNO_2$, with a redox potential of $+1.10$V.

The oxidation reaction is $NO_3^- + 3H^+ + 2e \rightarrow HNO_2 + H_2O$, with a redox potential of $+0.94$V.

The EMF of the cell is a positive value of $+0.16$V.

Therefore the overall redox reaction is spontaneous and will work under standard conditions.

(b) The half equations are:

$BrO_3^- + 6H^+ + 6e^- \rightarrow Br^- + 3H_2O$

$2I^- \rightarrow I_2 + 2e^-$

The overall balanced equation is:

$BrO_3^- + 6H^+ + 6I^- \rightarrow 3I_2 + Br^- + 3H_2O$ (ans)

06-1-Q-02

(i) $Mg_3N_2 + 6H_2O \rightarrow 3Mg(OH)_2 + 2NH_3$ (1)

(ii) Oxidation number of N in Mg_3N_2 is -3 (1)

Oxidation number of N in NH_3 is -3 (1)

Hence there is no redox reaction because there is no change in the oxidation no. of N (1)

(iii) Cl_2 will react with cold NaOH(aq):

$Cl_2(g) + 2NaOH(aq) \rightarrow NaCl\,(aq) + NaClO(aq) + H_2O(l)$

(iv) OH^- instead of Cl^- will be discharged at the anode to give O_2 gas.

(b) (i) Electrode **A**: $Zn(s) \rightarrow Zn^{2+}(aq) + 2e$
Electrode **C**: $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e$

(ii) Mole ratio of Cu : e : Ag = 1 : 2 : 1

No. of moles of Ag deposited
$= 2 \times \left(\frac{1.5}{63.5}\right) = 0.472$

Mass of Ag deposited $= 0.472 \times 108$
$= 5.10$ g (ans)

06-3-Q-08

07ZZ06-3-Q-08

(a) (i) Relative atomic mass of metal
$= (63 \times ¾) + (65 \times ¼) = 63.5$

(ii) $Q = 1 \times 30 \times 60 = 1800C$

No. of moles deposited $= \frac{0.5922}{63.5}$
$= 9.325 \times 10^{-3}$

1F will liberate $\left(\frac{96500}{1800}\right) \times 9.325 \times 10^{-3} = 0.5$ moles

Hence charge on the metal ion = +2

(iii) Mass of metal deposited $= 0.5 \times 63.5$
$= 31.75$ g

(b) (i) $O_2 + 4H^+ + 4Au \rightarrow 2H_2O + 4Au^+$
$E^\theta_{cell} = -0.46V < 0$

$3O_2 + 12H^+ + 4Au \rightarrow 6H_2O + 4Au^{3+}$
$E^\theta_{cell} = -0.27V < 0$

Gold does not tarnish or get oxidized in air as $E^\theta_{cell} < 0$ for both reactions.

(ii) $Au^+ \rightarrow 2Au + Au^{3+}$
$E^\theta_{cell} = +0.28V > 0$

Yes, it would disproportionate. The reaction is feasible.

(iii) Redox potential of $F_2/F^- = +2.87V$
Redox potential of $Au/Au^+ = +1.69V$
Redox potential of $Au^{3+}/Au = +1.50V$

Au^{3+} and F are formed. Au^+ will not be obtained as it will undergo disproportionation. (ans)

06-3-Q-09

07ZZ06-3-Q-09

(i) cathode: $2H_2O + 2e \rightleftharpoons H_2 + 2OH^-$

anode: $Cu(s) \rightleftharpoons Cu^{2+}(aq) + 2e$

(ii) Cu^{2+} formed at the anode oxidizes I^- to I_2, while Cu^{2+} reacts with I^- of the electrolyte to form white precipitate CuI. (ans)

06-3-Q-10

(i) anode: $Cl^-(aq) \rightarrow ½\,Cl_2(g) + e^-$ [1]
cathode: $H^+(aq) + e^- \rightarrow ½\,H_2(g)$ ***or***
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ [1]

(ii) because iron in steel will react with chlorine. [1]

the solubility of silver chloride and silver chromate(VI).

Addition of nitrate ions will have no effect on the ionic product of the ions involved, and thus would not lead to precipitation. (ans)

07-1-M-25

07ZZ07-1-M-25

C The % yield of Z is higher in graph 1 as compared to graph 2. The addition of a catalyst will not alter the position of equilibrium. As the forward reaction is exothermic, an increase in temperature will cause the system to favour the backward reaction, thus decreasing the yield of Z. The forward reaction also yields a higher number of gas molecules. Therefore an increase in pressure will be counteracted by favouring the backward reaction which produces fewer gas molecules. (ans)

07-1-M-26

07ZZ07-1-M-26

D A decrease in pressure moves the mercury column towards bulb B, showing that the forward reaction is favoured with a decrease in pressure. Therefore the forward reaction must be the one which produces more gas molecules. (ans)

07-1-M-27

A $$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

Since 2.32 mol of nitrogen were present in the equilibrium mixture, 0.32 mol must come from the reverse reaction.

$(2 \times 0.32) = 0.64$ mol of NH_3 is required to form 0.32 mol of N_2. Hence equilibrium amount of NH_3 is $(2.40 - 0.64) = 1.76$ mol

If 0.32 mol of N_2 were formed, $(3 \times 0.32) = 0.96$ mol of H_2 must have formed. Hence equilibrium amount of H_2 is $(6.00 + 0.96) = 6.96$ mol

Hence $K_c = \dfrac{(1.76)^2}{(2.32)(6.96)^3}$

07-1-M-28

C **Dynamic equilibrium** refers to the state of a chemical reaction whereby the rates of the *forward* and *backward* reactions are equal at equilibrium.

The system is reversible.

The composition of any substance (reactant or product) is unchanged at equilibrium.

The enthalpy change of a reaction at equilibrium is equal to zero.

07-1-M-29

A When the temperature of a system is increased, the rates of both the forward reaction and the backward reactions will increase.

A change in temperature will change the value of the equilibrium constant, K_c.

Increased temperatures favour endothermic reactions while decreased temperatures favour exothermic reactions.

Partial pressures of the gases increase with temperature.

The activation energy remains unchanged.

curve is proportional to the number of molecules present. (ans)

08-1-M-27

07ZZ08-1-M-27

B A catalyst increases the rate of reaction without altering the stoichiometry of the reaction and the position of equilibrium. More products are formed per unit time as the rate of reaction increases. (ans)

08-1-M-28

07ZZ08-1-M-28

B By comparing the results obtained for experiments 2 and 3, the doubling of [NO] will increase the rate of reaction by four times. Therefore the reaction is second order with respect to NO. By comparing the results obtained for experiments 1 and 2, the doubling of [O_2] will increase the rate of reaction by two times. Therefore the reaction is first order with respect to O_2. In the rate-determining step, two molecules of NO reacts with one molecule of O_2.

Rate = $k[\text{NO}]^2\,[\text{O}_2]$.

The overall order of the reaction is 1+2 = 3. The units for the rate constant = $\text{atm}^{-2}\ \text{s}^{-1}$. (ans)

08-1-M-29

07ZZ08-1-M-29

D The reaction is second order with respect to X. Therefore, doubling the pressure in the vessel will increase the rate of reaction by four times. The activation energy and rate constant are not altered by changes in pressure. The rate constant is only altered by changes in temperature and the addition of catalysts. (ans)

08-1-M-30

C An **autocatalyst** is a product of a chemical reaction which is capable of acting as a catalyst for the reaction.

The concentration of an autocatalyst increases as the reaction proceeds, hence the reaction rate increases as the reaction progress.

As the reactants are used up, the rate of reaction slows.

08-1-M-31

D The **Maxwell-Boltzmann distribution curve** shows how the speeds (and hence the energies) of a mixture of moving particles varies at a particular temperature.

The area under the curve is proportional to the total number of particles present..

The graph (dotted line) representing the distribution at –10°C has more molecules with higher energy. Hence it has larger area on the right of the graph.

However, it cannot be higher than the graph representing the distribution at –20°C, as the areas under the two curves are the same.

08-1-M-32

D Statement 1 is true; the activation energy of a chemical reaction has an effect on the reaction rate.

Statement 2 is false; the size of the enthalpy change does not affect the reaction rate.

Statement 3 is false; an equilibrium constant is a calculated value based on experimental observations made under certain conditions, it is not a “factor” that influences other properties.

RC*l*$_n$ has a lower melting and boiling point than **Q**C*l*$_m$. A small amount of energy is required to overcome the weak van der Waals' forces of attraction between the molecules. It is soluble in non-polar benzene solvent but insoluble in water as it is a simple covalent compound. **R**C*l*$_n$ molecules can form weak van der Waals' forces of attraction with benzene molecules.

(ii) Elements **Q** and **R** are in the same period. **Q** is probably a metal while **R** is a non-metal. Across the period, nuclear charge increases since atomic number increases. Increase in screening effect is almost constant since electrons are added to the same subshell. Hence effective nuclear charge increases. Electrostatic forces of attraction between the nucleus and outermost electrons increases. Hence the 1st IE of **R** is less exothermic than **Q**.

(b) No. of moles of $CO_2 = \frac{42.6}{24000} = 1.775 \times 10^{-3}$

Mole ratio of CO_2 : $\mathbf{X}CO_3.\mathbf{Y}CO_3 = 1 : 1$

No. of moles of $\mathbf{X}CO_3.\mathbf{Y}CO_3 = 1.775 \times 10^{-3}$

M_r of $\mathbf{X}CO_3.\mathbf{Y}CO_3 = 281.7$

Summation of A_r of X and Y $= 281.7 - 120$
$= 161.7$

Since X and Y are both Group II metals, X must be Mg and Y is Ba. (ans)

09-1-Q-20

07ZZ09-1-Q-20

The enthalpy change of vaporization is directly dependent on strength of metallic bonding.

From Sc to V, increase in number of valence electrons in 3*d* and 4*s* orbitals leads to stronger metallic bonds, hence more energy is needed to overcome them.

Mn only contributes 2 electrons to delocalized electron cloud, and hence $3d^5$ configuration is stable. It forms weak metallic bonds.

Zn has a stable $3d^{10}$ configuration as well, and therefore forms weak metallic bonds. (ans)

09-1-Q-21

(a) (i) metallic bonding. [1]

strength of attraction / metallic bonding increases (Na to A*l*) / more energy is needed to break 'bonds'. [1]

due to increasing cation charge / charge density / increasing number of delocalized electrons / decreasing ionic radius. [1]

(ii) van der Waals' forces [1]

are greatest / more in sulfur / relative magnitude of forces S > P > C*l* > Ar [1]

because sulfur has the greatest number of electrons / as no. of electrons (in the molecules) decreases. [1]

(iii) Covalent bonds broken OR

Si has a giant covalent structure [1]

(b) (i) Nuclear charge in Ar is greater than C*l* AND same shielding. [1]

(ii) *p* subshell / orbital in A*l* at higher energy than *s* subshell in Mg OR *p* subshell / orbital more shielded. [1]

(iii) repulsion due to electron pair (in same / *p* orbital). [1]

09-2-M-25

07ZZ09-2-M-25

B The lattice enthalpy of a compound is proportional to the product of the charges and inversely proportional to the sum of its cationic and anionic radii. The ionic radius of magnesium and lithium are almost similar while magnesium is of a higher charge than lithium. Therefore the lattice energy of magnesium chloride is larger than that of lithium chloride. (ans)

09-2-M-26

07ZZ09-2-M-26

D Down the group, the ionic radius increases, the first ionisation energy decreases and the elements becomes more stable thermally. The enthalpy change of hydration becomes less exothermic as the charge density decreases down the group. (ans)

09-2-M-27

07ZZ09-2-M-27

C Carbon dioxide gas is given off when calcium carbonate reacts with dilute hydrochloric acid. However, the white precipitate of barium sulphate will not dissolve in dilute hydrochloric acid. (ans)

09-2-M-28

07ZZ09-2-M-28

D The group II metals react vigorously with acids. The reactivity increases down the group as the redox potential becomes more negative. Therefore the reducing power of the elements increases down the group as they become oxidised more readily. (ans)

09-2-M-29

07ZZ09-2-M-29

D The valence electrons are held most strongly by the nucleus if the atomic radius is small. The element with a small atomic radius is most likely the one which is not as reactive as reactivity increases down the group. The redox potentials of the elements become more negative down the group, and thus the elements become better reducing agents. Therefore the element with a small atomic radius is most likely a weak reducing agent. (ans)

09-2-M-30

A When an aqueous solution of metal **X** reacts with sulfuric acid, it will give a sulfate of **X**.

Sulfates of Group I metals such as Na, K are soluble in water. Solubility of sulfates of Group II metals decreases down the group. Be and Mg sulfates are soluble in water, and Ca sulfate is sparingly soluble. The other Group II sulfates are insoluble in water.

Since a white precipitate is obtained when the solutions is mixed with aqueous sulfuric acid, metal **X** is barium.

09-2-M-31

B Down the group in Group II elements, the electronegativity of the elements decreases.

Down the group, the atomic and ionic radii increase.

The reactivity and reducing power of the elements increases down the group as it is easier to remove the outermost electrons. Hence maximum oxidation number decreases.

Down the group, the ionization energy of the elements decreases.

09-2-M-32

C Magnesium oxide is used as refractory lining material

Calcium carbonate, calcium hydroxide and calcium oxide are used as fertilizer for correcting acidity (liming).

09-2-M-33

B Although calcium is directly below magnesium in the Periodic Table it does not burn with a purely white flame. The flame seen when calcium burns is red.

Hence HI may not be obtained at the end of the reaction.

$2NaI + H_2SO_4 \rightarrow 2HI + Na_2SO_4$

$2HI + H_2SO_4 \rightarrow I_2 + SO_2 + H_2O$

(ii) Reagents: hydrogen gas and iodine gas

Conditions: 400°C, platinum catalyst

$H_2 + I_2 \rightleftharpoons 2HI$

Equilibrium mixture contains hydrogen gas, iodine gas and hydrogen iodide gas. (ans)

09-3-Q-22

07ZZ09-3-Q-22

(a) Chlorine is a better oxidising agent as compared to iodine as its redox potential (+1.36V) is more positive than that of iodine (+0.54V). This can be demonstrated by reacting chlorine and an iodide compound. The more reactive chlorine will displace the less reactive iodine from its aqueous halide ions.

$Cl_2 + 2HI \rightarrow 2HCl + I_2$

(b) White precipitate of AgCl and yellow precipitate of AgI will be formed. In excess NH_3, AgCl dissolves, due to the formation of $Ag(NH_3)_2^+$.

(c) (i) A is bromide ion (Br^-).

(ii) $2H^+ + BrO_x^- + 2I^- \rightarrow I_2 + Br^-$

(iii) No. of moles of thiosulphate ions

$= \left(\frac{28.3}{1000}\right) \times 0.7 = 0.0198$

Mole ratio of iodine : thiosulphate ions

$= 1 : 2$

No. of moles of iodine $= \frac{0.0198}{2} = 0.01$

Mole ratio of BrO_x^- : iodine

$\Rightarrow 0.01 : 0.01 \Rightarrow 1 : 1$

Therefore $x = 1$ in the above equation. The other product would be water. (ans)

09-3-Q-23

(a) sodium

burns with a yellow or orange flame or
forms a white solid
allow – once only – colour of chlorine disappears [1]

$2Na + Cl_2 \rightarrow 2NaCl$ [1]

phosphorus

burns with a white or yellow flame or
colour of chlorine disappears – if not given for Na

or

for PCl_5 forms a white or pale yellow solid
for PCl_3 forms a colourless liquid [1]

$P + 2\frac{1}{2}Cl_2 \rightarrow PCl_5$ or $P_4 + 10Cl_2 \rightarrow 4PCl_5$

or

$P + 1\frac{1}{2}Cl_2 \rightarrow PCl_3$ or $P_4 + 6Cl_2 \rightarrow 4PCl_3$
equation must refer to compound described [1]

(b)

condition	formula of other chlorine-containing compound	oxidation number of chlorine in this compound
cold dilute NaOH(aq)	NaOCl	+1
hot concentrated NaOH(aq)	$NaClO_3$	+5

[4]

(c) $MgCl_2$: 6.5 to 6.9 [1]

$SiCl_4$: 0 to 3 [1]

$MgCl_2$ dissolves without reaction or slight or partial hydrolysis occurs [1]

$SiCl_4$ reacts with water or hydrolysis occurs [1]

$SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$ or
$SiCl_4 + 4H_2O \rightarrow Si(OH)_4 + 4HCl$ or
$SiCl_4 + 4H_2O \rightarrow SiO_2.2H_2O + 4HCl$ [1]

09-3-Q-24

(a) (i) Identity of K is chloride Cl^- or F^- fluoride [1]

Equation for reaction: [1]

$H_2SO_4 + 2NaCl \rightarrow Na_2SO_4 + 2HCl$ (or equation with F) OR

$H_2SO_4 + NaCl \rightarrow NaHSO_4 + HCl$ (or equation with F)

Explanation of observation: [1]

Halide HK is acidic OR HK is a gas OR an acidic gas is produced.

(ii) Identity of L is I^- iodide [1]

Colour of precipitate is yellow [1]

Equation for reaction: [1]

$Ag^+ + I^- \rightarrow AgI$ OR

$AgNO_3 + NaI \rightarrow AgI + NaNO_3$

(iii) Identity of M_2 is bromine Br_2. [1]

Explanation: [1]

Bromine has fewer electrons than iodine OR bromine has more electrons than chlorine

Intermolecular / van der Waals' forces in bromine is weaker than in iodine, or stronger than in chlorine.

(b) (i) B is chlorine (Cl_2) [1]

C is hydrogen (H_2) [1]

D is sodium hydroxide (NaOH) [1]

(ii) anode: $2Cl^- \rightarrow Cl_2 + 2e^-$ [1]

cathode: $2H^+ + 2e^- \rightarrow H_2$ OR

$2H_2O + 2e^- \rightarrow 2OH^- + H_2$ [1]

❾•❹ An introduction to the chemistry of transition elements

MCQs

09-4-M-01

07ZZ09-4-M-01

D The reaction of metals with acidic solutions will cause the production of effervescence which is hydrogen gas. Therefore the iron (III) chloride solution is acidic. (ans)

09-4-M-02

07ZZ09-4-M-02

B R: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^2$

R is a transition element which is able to exhibit a variety of oxidation states due to the close similarity in energy of the 4*s* and 3*d* electrons. Therefore, R is able to exhibit four different oxidation states, from +1 to +4. R in K_2RO_4 has an oxidation state of +6, and thus is not likely to exist. (ans)

09-4-M-03

07ZZ09-4-M-03

A Iron is a transition element while calcium is not. Therefore, iron is able to exhibit variable oxidation states due to the close similarity in energy of the 4*s* and 3*d* electrons. The transition elements are also very dense as the atomic volume is smaller than calcium due to the smaller atomic radius and closely packed structures. Calcium reacts with cold water to give hydrogen gas while iron will not. (ans)

09-4-M-04

07ZZ09-4-M-04

C Copper has an atomic number of 29. Its electronic configuration is $3d^{10}\ 4s^1$. The electronic configuration of Cu^{2+} in the complex $[Cu(NH_3)_4]^{2+}$ is $3d^9$ and not $3d^{10}$ since ammonia is an uncharged ligand. (ans) they form six dative bonds with the central copper (II) ion. This is not a redox reaction as the oxidation state of copper remains at +2. (ans)

09-4-M-41

07ZZ09-4-M-41

B CH_3CH_3 cannot act as a ligand as it does not have unshared pairs of electrons and thus cannot form dative bonds. (ans)

09-4-M-42

07ZZ09-4-M-42

D The atomic radii of the first row transition elements remain relatively constant as the inner 3*d* subshell provides an effective shield between the outer 4*s* electrons and the nucleus, hence nullifying the influence of each additional proton in the nucleus due to the increasing nuclear charge across the period. Thus the increase in effective nuclear charge is very small. (ans)

09-4-M-43

07ZZ09-4-M-43

B CH_3CH_3 cannot act as a ligand as it does not have unshared pairs of electrons and thus cannot form dative bonds. (ans)

09-4-M-44

07ZZ09-4-M-44

C Q has an electronic configuration of $3d^5 4s^1$ and will thus be able to exhibit six oxidation states, from +1 to +6. Therefore Q_2O_3 (oxidation state of Q = +3) is likely to exist.

T is a transition element as it has a partially filled 3*d* subshell, thus its electrons can absorb visible light in *d-d* transition to give coloured ions. The redox potential of S^{3+}/S^{2+} is more positive than that of R^{3+}/R^{2+} as the redox potentials becomes more positive across the period as ionization energy and electronegativity increases. The electronic configuration of P^{3+} is $[Ar]3d^2\ 4s^2$. (ans)

09-4-M-45

07ZZ09-4-M-45

C Transition elements are harder than the *s*-block elements as they have stronger metallic bonding. They can form coloured compounds as they have a partially filled 3*d* subshell whose electrons can undergo *d-d* transition by absorbing visible light. They also do not melt easily as they have strong metallic bonds due to the availability of both the 3*d* and 4*s* electrons for delocalisation, and thus have high melting points. (ans)

09-4-M-46

07ZZ09-4-M-46

B Cu^{2+} ions must have catalysed side reactions producing compounds of nitrogen, thus reducing the concentration of sodium hypochlorite. Copper is able to function as a catalyst due to its ability to exhibit multiple oxidation states and the availability of the partially filled 3*d* subshell. Therefore the yield of hydrazine drops drastically when copper (II) ions are present. (ans)

09-4-M-47

C Vanadium (V) oxide is used as catalyst for the manufacture of sulfuric acid in the Contact process.

Finely-divided iron is the catalyst for the manufacture of ammonia in the Haber process.

molecule, resulting in a higher boiling point for the second molecule. (ans)

10-1-M-31

07ZZ10-1-M-31

C Compound Z has one chiral centre and exhibits cis-trans isomerism about its carbon-carbon double bond. Therefore it has four stereoisomers. The chiral carbon is the atom which is attached to the hydroxyl group. (ans)

10-1-M-32

07ZZ10-1-M-32

B Compound A has one chiral centre and exhibits cis-trans isomerism about its carbon-carbon double bond. Therefore it has four stereoisomers.

The chiral carbon is the atom which is attached to the chlorine atom. The compound will decolourise bromine water as electrophilic addition can occur at the carbon-carbon double bond.

Optical isomers differ in the direction of rotation of the plane of vibration of polarized light. It is not a monomer of condensation polymer as water is not formed in the production of a polymer. However, addition polymerisation can occur as a carbon-carbon double bond is present in the molecule. (ans)

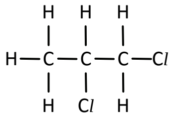
10-1-M-33

07ZZ10-1-M-33

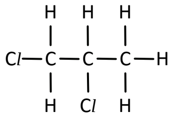
C An acyl chloride such as X would be most acidic as it reacts with water to form acids. Amides like Y are neutral compounds which do not donate or accept protons. Z is a salt made from a weak base and a strong acid. Thus its pH will be slightly acidic but not as acidic as that of the acyl chlorides. Therefore the compounds arranged in order of increasing pH is X, Z, Y. (ans)

10-1-M-34

B $CH_3CHClCH_2Cl$ (1,2-dichloropropane) exhibits stereoisomerism.



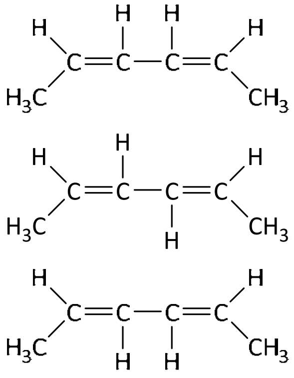
$H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{Cl}{C}}-\overset{H}{\underset{H}{C}}-Cl$



$Cl-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{Cl}{C}}-\overset{H}{\underset{H}{C}}-H$

10-1-M-35

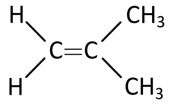
C There are three geometrical (cis-trans) isomers of hex-2,4-diene, $CH_3CH{=}CHCH{=}CHCH_3$.



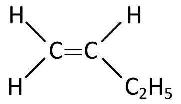
10-1-Q-09

07ZZ10-1-Q-09

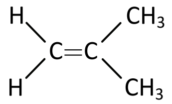
(i)



Geometric isomerism with **P**

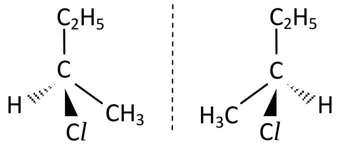


Positional isomerism with **P**



Structural isomerism with **P**

(ii)



(ans)

10-1-Q-10

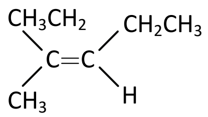
07ZZ10-1-Q-10

(i)

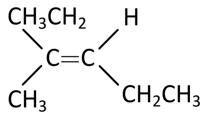
	C	H
%	85.7	14.3
A_r	12	1
Mole Ratio	7.14	14.3
	1	2

Empirical formula of **C**: CH_2

(ii)

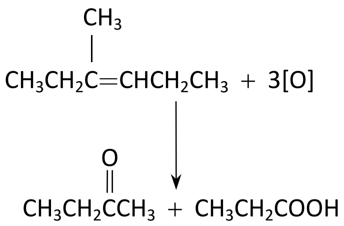


cis-3-methylhex-3-ene



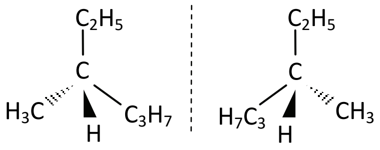
trans-3-methylhex-3-ene

(iii)



$$CH_3CH_2\overset{\displaystyle CH_3}{\overset{|}{C}}{=}CHCH_2CH_3 + 3[O] \longrightarrow CH_3CH_2\overset{\displaystyle O}{\overset{\|}{C}}CH_3 + CH_3CH_2COOH$$

(iv) **D** exhibits optical isomerism due to the presence of a chiral carbon, non-superimposable mirror images and no plane of symmetry.



(ans)

10-1-Q-11

07ZZ10-1-Q-11

(a) Tetrachloromethane does not contain any protons, therefore it does not give a signal in the NMR spectrum, no interference with signals of sample.

(b) All the twelve protons in TMS are chemically equivalent, thus resonate as the same frequency to give only 1 signal which does not cause interference to the rest of the signals in the spectrum of the sample.

(c) (i) Propan-1-ol: 4 signals (triplet, multiplet, triplet and singlet with relative intensities of 3:2:2:1 respectively).

Propan-2-ol: 3 signals (doublet, multiplet and singlet with relative intensities of 6:1:1 respectively).

(ii) Propanal: 3 signals (triplet, quartet and singlet with relative intensities of 3:2:1 respectively).

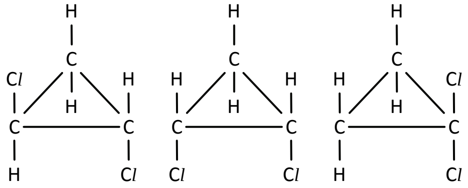
Propanone: 1 signal (one singlet). (ans)

10-1-Q-12

(a) 117° to 120° [1]

(b) (i) electrophilic addition [1]

(ii)



[3]

❿•❷ Hydrocarbons

MCQs

10-2-M-01

07ZZ10-2-M-01

A Free-radical substitution involves three steps, namely initiation, propagation and termination. In initiation, hemolytic fission of chlorine molecules produces chlorine free radicals. In propagation, the chlorine free radicals react with methane, abstracting a hydrogen atom to form hydrogen chloride and the methyl free radical. The methyl radical will react with other chlorine molecules to form methyl chloride and more chlorine free radicals. The process goes on indefinitely in a chain reaction. The chain reaction is then terminated when two free radicals combine. Hydrogen chloride is not likely to be formed in the termination step as the hydrogen free radical is not formed in the reaction. (ans)

10-2-M-02

07ZZ10-2-M-02

D Since one mole of **Y** reacts with two moles of aqueous bromine, **Y** must have two carbon-carbon double bonds in its structure in order to take part in electrophilic addition reaction with aqueous bromine. On strong oxidation with hot aqueous potassium permanganate, compound **Y** yields carbon dioxide gas and a compound with formula $C_2H_4O_2$ as the only products. Therefore, **Y** yields as a carboxylic acid CH_3COOH as its product. During strong oxidation, the carbon-carbon double bond is broken, and the side groups oxidized. Therefore, **Y** must contain the $CH_3CH–$ group at the carbon-carbon double bond. Y must contain CH– groups in its structure which will be oxidized to produce carbon dioxide. The structure of **Y** is most likely

$CH_3CH{=}CH{-}CH{=}CHCH_3$ (ans)

10-2-M-03

07ZZ10-2-M-03

C But-1-ene does not exhibit geometrical isomerism as one of its carbon atoms at the double bond do not have two different substituents attached to it. It gives a carboxylic acid and carbon dioxide on

10-2-M-43

07ZZ10-2-M-43

B Linalool has a hydroxyl group and its aqueous solution is considered to be neutral. It undergoes mild oxidation on addition of cold alkaline potassium manganate (VII) solution as it contains carbon-carbon double bonds to produce a diol and carbon dioxide gas. The gas is observed as effervescence. It contains carbon-carbon double bonds and thus undergoes electrophilic addition when reacted with bromine. Decolourisation of bromine and evolution of white fumes are observed. Linalool has two pairs of stereoisomers as it has a chiral carbon and exhibits geometrical isomerism. The chiral carbon is marked with an asterisk.

$$(CH_3)_2\underbrace{C=C}_{\text{geometrical isomers}}HCH_2CH_2{}^*C(CH_3)(OH)CH=CH_2$$

(ans)

10-2-M-44

07ZZ10-2-M-44

C As the polymer is saturated, it can undergo free radical substitution which is characteristic for all alkanes. It is an addition polymer formed from unsaturated compounds. The polymer is in multiples of C_3H_6, thus its empirical formula is CH_2. Most plastics formed by addition polymerisation are non-biodegradable. (ans)

10-2-M-45

07ZZ10-2-M-45

C No. of moles of carbon dioxide $= \frac{17.6}{44} = 0.4$

Mole ratio of X : carbon dioxide $\Rightarrow 0.1 : 0.4$
$\Rightarrow 1 : 4$

No. of moles of bromine vapour $= \frac{4.48}{24} = 0.187$

Mole ratio of X : bromine vapour $\Rightarrow 0.1 : 0.187$
$\Rightarrow 1 : 2$

From the ratio of X : bromine vapour, it can be deduced that X has two carbon-carbon double bonds.

From the ratio of X : carbon dioxide, it can be deduced that X contains four carbon atoms. Therefore X is:

$CH_2{=}CHCH{=}CH_2$ (ans)

10-2-M-46

07ZZ10-2-M-46

D The reaction between methane and bromine in the presence of light occurs by free radical substitution. Free radicals are formed as intermediates. A possible intermediate is $\bullet CH_2Br$. It is not possible to form free radicals containing more than one bromine atom. (ans)

10-2-M-47

07ZZ10-2-M-47

C Catalytic cracking breaks down the carbon-carbon bonds in long chain alkane molecules to produce smaller molecules of alkanes, alkenes and hydrogen. It does not produce petrol of lower octane number. (ans)

10-2-M-48

07ZZ10-2-M-48

B Catalytic converters remove pollutant gases before they reach the atmosphere. On the surface of the converter, oxides of nitrogen and carbon monoxide are converted to nitrogen and carbon dioxide gas. Carbon monoxide and oxygen is also converted to carbon dioxide. Hydrocarbons and oxygen are converted to water and carbon dioxide gas. Carbon monoxide does not react with the hydrocarbons in a converter. (ans)

10-2-M-49

B Chlorine atoms are homolytically cleaved to form chlorine free radicals in the presence of ultraviolet light or heat. As the activation energy of this reaction is high, it requires energy from ultraviolet light or heat to proceed.

$$Cl_2 \xrightarrow[\text{light}]{\text{ultraviolet}} Cl\bullet + Cl\bullet$$

Conversely, the formation of chlorine atom from chlorine free radicals has lowest activation energy.

10-2-Q-19

07ZZ10-2-Q-19

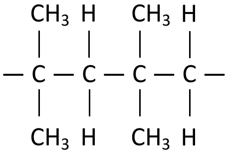
ΔH^{θ} (cyclohexa-1, 3, 5-triene)
$= -120\ \text{kJ mol}^{-1} \times 3$
$= -360\ \text{kJ mol}^{-1}$

Benzene is more stable than cyclohexa-1, 3, 5-triene by 152 kJ mol^{-1}. The actual structure of benzene consists of a system of delocalised *p* electron clouds which confers stability to the benzene molecule. (ans)

10-2-Q-20

07ZZ10-2-Q-20

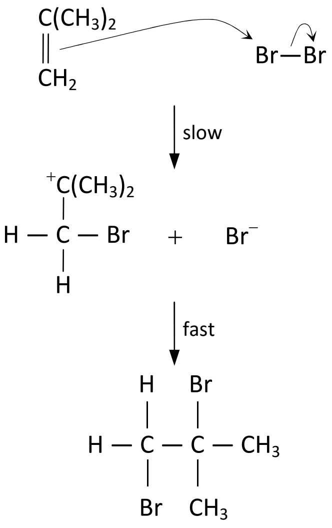
(a) Structure of two repeat units of the polymer:



$$-\overset{CH_3}{\underset{CH_3}{C}}-\overset{H}{\underset{H}{C}}-\overset{CH_3}{\underset{CH_3}{C}}-\overset{H}{\underset{H}{C}}-$$

(b) (i) Conditions: absence of uv light, room temperature.

(ii) Mechanism of electrophilic addition.



(ans)

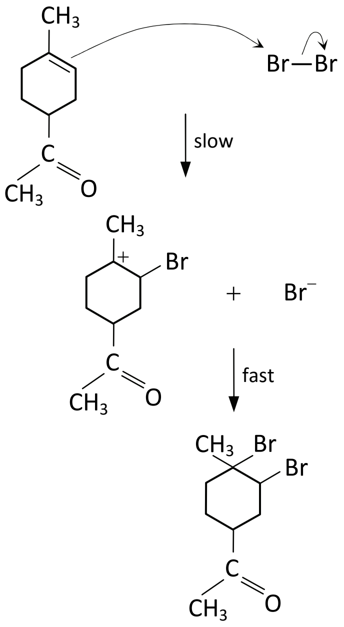
10-2-Q-21

07ZZ10-2-Q-21

Electrophilic addition reaction.

Step 1: The electrophilic end of HBr molecule forms a σ bond with one of the unsaturated C atom resulting in the formation of a carbocation intermediate.

Step 2: Combination of carbocation with bromide ions to form the addition product.



(ans)

10-2-Q-22

(a) (i) alkanes or paraffins (not hydrocarbons) [1]

(ii) $2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$ [1]

(b) (i) carbon (allow graphite) [1]

(ii) $2C_4H_{10} + 5O_2 \rightarrow 8C + 10H_2O$
allow balanced equations which include CO and/or CO_2 [1]

(c) (i) from methane to butane
there are more electrons in the molecule [1]
therefore greater/stronger van der Waals' forces [1]

(ii) straight chain molecules can be packed more closely [1]
therefore stronger van der Waals' forces [1]
or reverse argument

10-2-Q-23

(a) Decolourisation with an alkene at room conditions quickly OR alkane needs higher temp / UV / is slow at room conditions. [1]

Double pi bond / C═C present in alkenes. [1]

(b) (i) UV light / sunlight / high temperature [1]

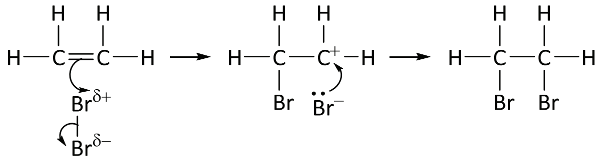
(ii) (Free) radical [1]
Substitution [1]

(iii) $\bullet C_2H_5 + \bullet C_2H_5 \rightarrow C_4H_{10}$ [1]

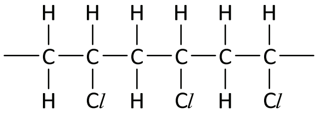
(iv) $C_2H_5Br + Br\bullet \rightarrow \bullet C_2H_4Br + HBr$ OR
$\bullet C_2H_4Br + Br_2 \rightarrow C_2H_4Br_2 + Br\bullet$ [1]

(c) (i) Electrophilic [1]
Addition [1]

(ii) 2 correct curly arrows [1]
correct dipole [1]
correct intermediate [1]
curly arrow from lone pair on Br^- to C^+ [1]



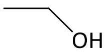
(d) Minimum of three repeat units [2]



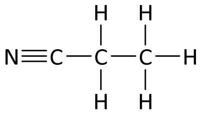
$$-CH_2-CHCl-CH_2-CHCl-CH_2-CHCl-$$

(e) (i) Reagent: NaOH / KOH [1]
ethanolic / alcoholic AND heat / reflux [1]

(ii) [1]



(iii) [1]



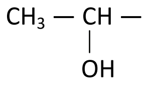
$$N\equiv C-CH_2-CH_3$$

Propanenitrile / propanonitrile / propionitrile / ethyl cyanide / cyanoethane [1]

10-3-M-25

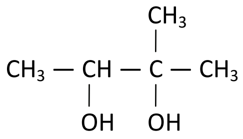
07ZZ10-3-M-25

B Since **X** exhibits optical activity, It must have a chiral carbon which is a carbon atom attached to four different substituents. Warming **X** with alcoholic KOH results in the elimination of a hydrogen bromide from **X**. The major alkene would be the one with the most alkyl substituents on the carbon-carbon double bond. The alkene will react with warm acidified potassium manganate (VII) and be oxidized to produce a diol. Since the product gives a positive tri-iodomethane test, it must contain the



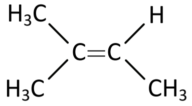
$CH_3-CH(OH)-$ group

The formula of the diol formed could be:



$CH_3-CH(OH)-C(OH)(CH_3)-CH_3$

Since there are five carbon atoms in the original compound **X**, the alkene **Y** would thus be:



The formula of **X** would be $CH_3CH(CH_3)CHBrCH_3$. (ans)

10-3-M-26

07ZZ10-3-M-26

B Phenols do not undergo esterification with carboxylic acids. Esterification only occurs between the phenolic group and an acyl chloride. Chlorobenzene is unreactive as the C–C*l* bond is short and strong, and thus is difficult to break. The benzene ring does not take part in free radical substitution, unlike alkanes. However, electrophilic substitution can occur with the appropriate reagents in order to produce chlorobenzene. The –CN group attached to an aliphatic carbon chain can be hydrolysed using dilute sodium hydroxide followed by acidification to give a carboxylic acid. (ans)

10-3-M-27

07ZZ10-3-M-27

D The boiling point increases from CH_3CH_2Cl to CH_3CH_2Br to CH_3CH_2I due to the increasing size of the halogens from chlorine to bromine to iodine. As the relative molecular mass of the molecules increases, the strength of the van der Waals' forces of attraction between the molecules increases, and thus requires more energy to break. (ans)

10-3-M-28

07ZZ10-3-M-28

D The hydrocarbon Y reacts with chlorine without evolving white fumes of hydrogen chloride. Therefore, the hydrocarbon must have carbon-carbon double bonds in its structure, and all of the chlorine molecules must be incorporated into the product.

One mole of the molecule in 1 will react with two moles of chlorine.

% of chlorine by mass in 1

$= \left(\frac{142}{238}\right) \times 100 = 59.7\ \%$

One mole of the molecule in 2 will react with one mole of chlorine.

% of chlorine by mass in 2

$= \left(\frac{71}{167}\right) \times 100 = 42.5\ \%$

One mole of the molecule in 3 will react with one mole of chlorine.

% of chlorine by mass in 3

$= \left(\frac{71}{167}\right) \times 100 = 42.5\ \%$

Therefore Y could be:

$CH_3CH{=}CHCH{=}CHCH_2CH_3$ (ans)

10-3-M-29

C Halogenoalkanes can be produced from their corresponding alcohols.

To produce chloroalkanes, react the alcohols with:

- PCl_5 at room temperature;
- dry HC*l* gas in the presence of $ZnCl_2$, reflux; and
- $SOCl_2$ in the presence of pyridine, heat.

10-3-M-30

A S_N2 is a continuous one-step process involving the attack by a nucleophile on a carbon atom with a partial positive charge.

10-3-M-31

B A precipitate of silver halide is produced from the reaction between a halogenoalkane and aqueous or alcoholic silver nitrate.

The identity of the halogen can be deduced from the colour of the precipitate. (AgC*l*: white; AgBr: cream; AgI: yellow)

Precipitate	Solubility
AgC*l*	precipitate dissolves in ammonia solution to give a colourless solution
AgBr	precipitate is sparingly soluble in dilute ammonia solution, but dissolves in concentrated ammonia solution to give a colourless solution
AgI	precipitate is insoluble in ammonia solution

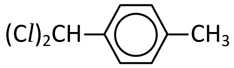
Questions – 10.3

10-3-Q-01

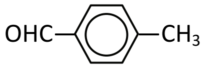
07ZZ10-3-Q-01

Identity of:

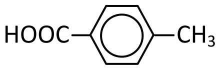
G:



H:



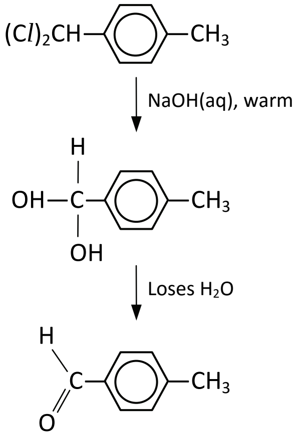
I:



J:

K: $HOCH_2CH_2OH$

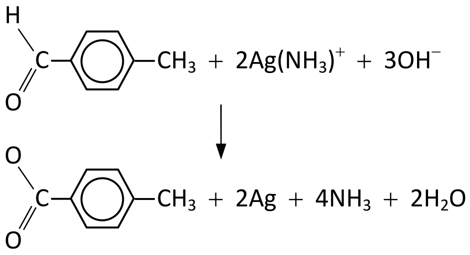
When **G** is warmed with sodium hydroxide,



H

When **H** reacts with silver diammine and 2, 4-dinitrophenylhydrazine, the two equations are expected to be balanced and as follows:

With silver diammine,



Thus the products are $CH_3CO_{18}OH$ and C_2H_5OH. (ans)

10-4-M-36

07ZZ10-4-M-36

B Phenols react with bromine at room temperature to form a creamy-white precipitate of 2, 4, 6-tribromophenol in a process known as halogenation. The yellow solution contains unreacted phenol as well as bromine. As phenol is slightly acidic, the yellow solution is not alkaline. (ans)

10-4-M-37

C The oxidising agents will change colour:

- orange to green for acidified potassium dichromate solution.
- purple to colourless for acidified potassium permanganate solution.

10-4-M-38

A Alcohol can be prepared in the laboratory by:

- Hydrolysis of alkenes
- Hydrolysis of halogenoalkanes
- Reduction of carbonyl compounds (ketones and aldehydes)

10-4-M-39

A The three alcohols given are isomeric so 74.00 g is 1.00 mol in each case:

1 mole of $C_4H_{10}O = (4 \times 12) + (10 \times 1) + (1 \times 16)$
$= 74.00g$

The question therefore rests on whether the given mass represents 0.62 mol of the given product.

0.62 mol butanone C_4H_8O
$= [(4 \times 12) + (8 \times 1) + (1 \times 16)] \times 0.62$
$= 44.64g$

0.62 mol butanoic acid $C_4H_8O_2$
$= [(4 \times 12) + (8 \times 1) + (2 \times 16)] \times 0.62$
$= 54.56g$

0.62 mol 2-methylpropanoic acid $C_4H_8O_2$
$= [(4 \times 12) + (8 \times 1) + (2 \times 16)] \times 0.62$
$= 54.56g$

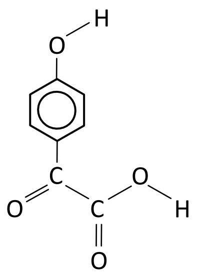
Questions – 10.4

10-4-Q-01

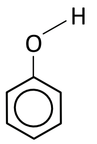
07ZZ10-4-Q-01

(a) The phenol group in **W** can undergo acid-base reaction with aqueous sodium hydroxide to give an ionic salt which ionizes readily in water. The two big non-polar benzene rings in **W** prevent effective hydrogen bonding between molecules of **W** and water.

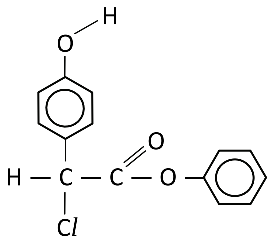
(b) (i)



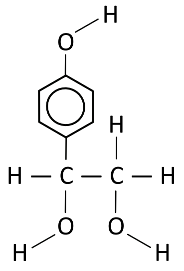
and



(ii)



(iii)



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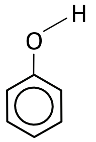
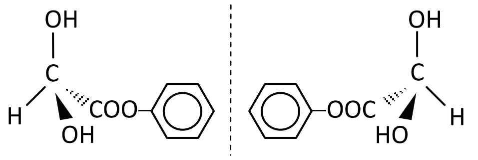


(c) Optical isomerism.

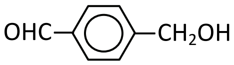


(ans)

10-5-M-26

07ZZ10-5-M-26

D Since the compound gives a positive test with 2, 4-dinitrophenylhydrazine, it must be a carbonyl compound. Carbonyl compounds are also neutral. Being neutral, the compound does not contain strongly acidic groups such as –COOH, or alkaline groups such as $-NH_2$. As the compound reacts with PCl_5, it must contain either the –OH or –COOH groups. The –OH group is very weakly acidic. Therefore the compound could be:



10-5-M-27

07ZZ10-5-M-27

B The compound contains an aldehyde group which can be oxidized by potassium dichromate (VI) despite being attached to the benzene ring. The colour of potassium dichromate (VI) will change from orange to green. Neutral iron (III) chloride will react with phenols to form a violet complex. Aqueous alkaline iodine will also react with the compound to give a yellow precipitate due to the presence of the CH_3CO group. Benzaldehyde does not react with Fehling's solution. (ans)

10-5-M-28

07ZZ10-5-M-28

A The carbon atom of the isocyanate group will be attacked by nucleophiles as it is surrounded by electronegative atoms such as nitrogen and oxygen, leaving it very electron deficient and susceptible to nucleophile attacks. (ans)

10-5-M-29

B $CH_3CH_2OH \xrightarrow[-2[H]]{\text{Cu catalyst}} CH_3CHO$:

<u>Dehydrogenation</u> of ethanol to ethanal (an aldehyde)

$CH_3CHO \xrightarrow[+\ CH_3CH_2OH]{\text{Cu catalyst}} CH_3CH(OH)OCH_2CH_3$:

<u>Nucleophilic addition</u> reaction of ethanal and ethanol to form acetaldehyde aldol

$CH_3CH(OH)OCH_2CH_3 \xrightarrow[-2[H]]{\text{Cu catalyst}} CH_3CO_2CH_2CH_3$:

<u>Dehydrogenation</u> of acetaldehyde aldol to ethyl ethanoate

10-5-M-30

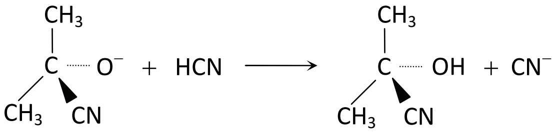
B Aldehydes is oxidised by Tollens' Reagent to form a *grey precipitate* of silver (silver mirror).

$CH_3CH_2CH_2CHO + 2Ag(NH_3)_2^+ + 3OH^- \rightarrow$
$CH_3CH_2CH_2COO + 2Ag + 4NH_3 + 2H_2O$

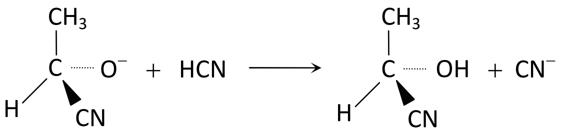
10-5-M-31

D A chiral center is defined as an atom in a molecule that is bonded to <u>four</u> different chemical species.

The product of an aldehyde and hydrogen cyanide does not possess a chiral centre:



The product of a ketone and hydrogen cyanide has a chiral centre:



Halogenoalkanes do not react with hydrogen cyanide.