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CHEMISTRY
PHYSICAL CHEMISTRY

Level & Board	CIE (A-LEVEL)
TOPIC:	ATOMS, MOLECULES & STOICHIOMETRY
PAPER TYPE:	SOLUTION - 1
TOTAL QUESTIONS	13
TOTAL MARKS	100

Atom, Molecules & Stoichiometry - 1

Solution 1

(a) (i) $n_{NaC/O_3} = \dfrac{10^6}{23 + 35.5 + 3(16)} = 9390\,mol$

$n_{e^-} = 6 \times n_{C/O_3^-} = 56340 \times 10^9 C$

$Q = n_{e^-} \times F = 56340 \times 96500 = 5.437 \times 10^9 C$

$I = \frac{Q}{t} == \frac{5.437\times10^9}{24\times60\times60} = 6.29 \times 10^4 A$

(ii) $n_{H_2} = 3 \times n_{NaC/O_3}\ 3 \times 9390 = 28170\,mol$

$V_{H_2} = n_{H_2} \times 24dm^3 = 28170 \times 24 = 6.76 \times 10^5 dm^3$

Solution 2

(c) (i) $6Fe^{2+} + Cr_2O_7^{2-} + 14H^+ \longrightarrow\ 6Fe^{3+} + 2Cr^{3+} + 7H_2O$

Additional chemical required: dilute sulphuric acid

grind the tablets into powdwr. Weigh a sample and dissolve

flask.

Pipette $25.0cm^3$ *of the* $FeSO_4$ *solution into a conical flask.*

Add in sufficient (say $10cm^3$*) of dilute* H_2SO_4 *using a measuring cylinder.*

Add in a few drops of ferroin indicator. The solution should appera or −

ange − red.

Titrate the solution with $K_2Cr_2O_7$ *from a burette until the colour of the*

solution turns greenish − blue.

From the titre value, we can determine the concentration Fe^{2+} *in the*

solution, and the actual mass of $FeSO_4$ *can then be calculated.*

(ii) $n_{Cr_2O_7^{2-}} = 0.025 \times \frac{10.50}{1000}$

$= 2.625 \times 10^{-4} mol$

$n_{Fe^{2+}} = 6 \times n_{Cr_2O_7^{2-}}$

$= 1.575 \times 10^{-3} mol = n_{Fe}$

$m_{Fe} = n_{Fe} \times 55.8$

$= 8.79 \times 10^{-2} g$

Solution 3

(c) (i) *It is a substance that speeds up a chemical reactio by lowering activation energy without being used up in the process.*

(ii) $2H_2O_2(aq) \longrightarrow H_2O(l) + O_2(g)$

(b) (i) *Alkanes*

(ii) $C_{15}H_{32}$ *needs* 23 *moles of oxygen for combustion.*

2 *moles of* H_2O_2 *can provide* 1 *mole of* O_2.

So one mole of $C_{15}H_{32}$ *needs* 16 *moles of* H_2O_2

(c) (i) $C_{15}H_{32} = 212$

$n(C_{15}H_{32}) = \frac{212 \times 10^6}{212}$

amount of diesel fuel $= 1 \times 10^8$ *mole*

(ii) (H_2O_2) *required* $= 46 \times 10^6$ *mole*

mass of $H_2O_2 = 34 \times 46 \times 10^6$

$= 1.564 \times 10^9 = 1564$ *tonnes*

(d) *The exaust products* H_2 *and* H_2, *both are soluble in water.*

(d) *They would dissolve.*

Solution 4

(a) *Solution of the sulphates decrease down the group. As the cationic size increase down the group, therefore both lattic energy and hydration energy decrease. The decrease in hydration energy is more than the decrease in lattice energy.*

(c) (i) $n(CO) = \frac{PV}{RT} = \frac{(1.01\times10^5)(140\times10^{-3})}{8.31\times450} = 3.78\, moles$

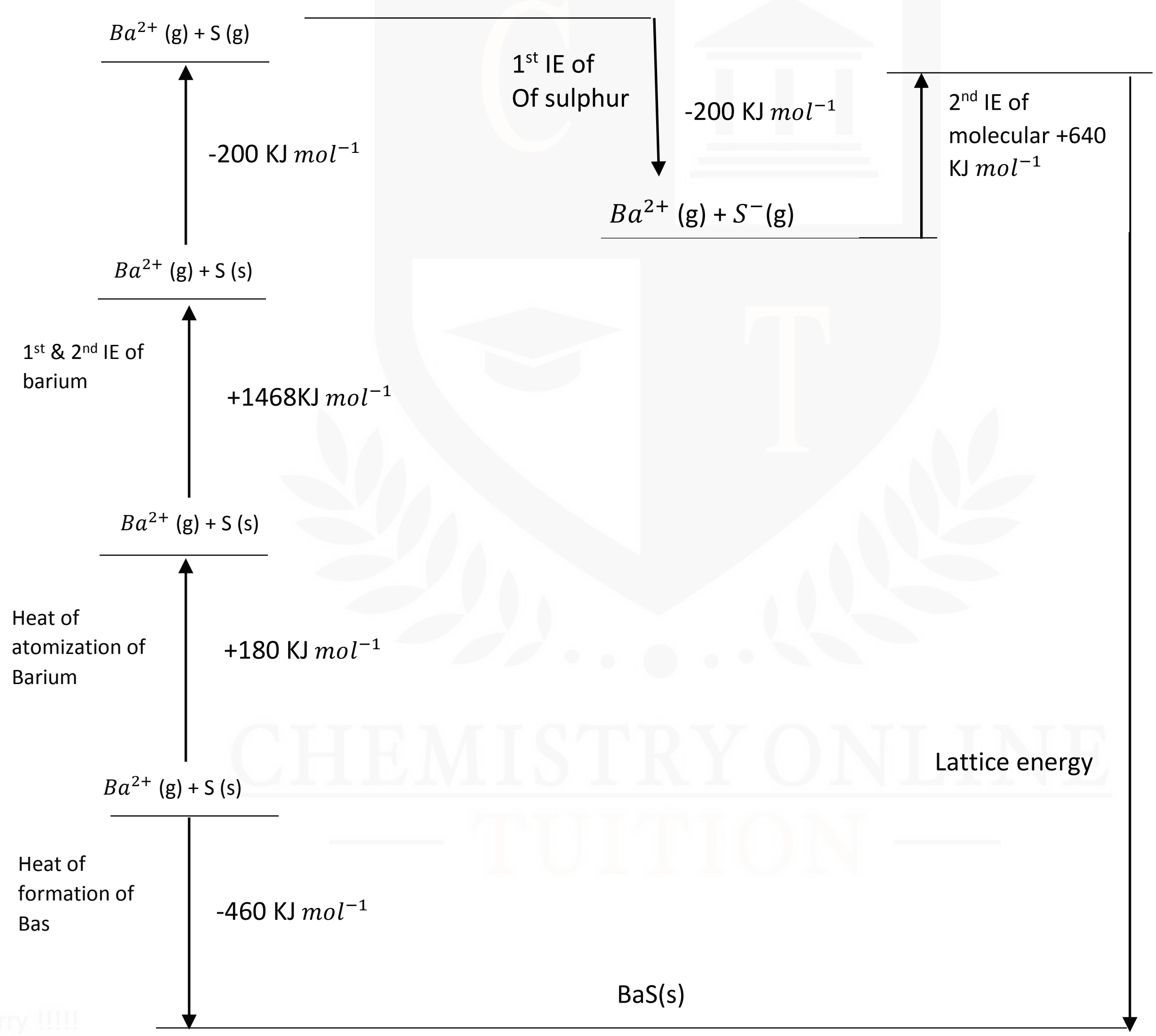
(ii) $n(BaSO_4) = \frac{n(CO)}{4} = \frac{3.78}{4} = 0.945\, moles$

(iii) $M_r(BaSO_4) = 137 + 32 + (16 \times 4) = 233$

$mass\ of\ BaSO_4 = 0.945 \times 233 = 220.2g$

$\%\ of\ BaSO_4\ in\ ore = \frac{220.2}{250} \times 100 = 88.1\%$

(c) (i)



$$\Delta H^\Theta_{atom(Ba)} + \Delta H^\Theta_{IE1st\ \&\ 2nd\ Ba\ (g)} + \Delta H^\Theta_{atom(S)} + \Delta H^\Theta_{EA\ 1st(S)} + \Delta H^\Theta_{EA\ 2nd(S)} + \Delta H^\Theta_{LE\ (BaS)} = \Delta H^\Theta_{f\ (BaS(s))}$$

$$180 + 1468 + 279 + 640 - 200 + Lattice\ energy = -460$$

$$2367 + Lattice\ energy = -460$$

$$Lattice\ energy = 02827\ KJmol^{-1}$$

(ii) $Lattice\ energy\ of\ BaS\ will\ be\ less\ than\ BaO, since\ the\ size\ of$

$S^{2-}\ ion\ is\ bigger\ than\ O^{2-}\ ion.$

(c) (i) S^{2-} ion being larger in size than O^{2-} ion, its charge density will be less than that of O^{2-} ion, therefore LE of BaS will be less than BaO.

Solution 5

(a) $The\ molecular\ formula\ specifices\ the\ actual\ number\ of\ atoms\ of\ each\ element\ in\ one\ molecule\ of\ a\ comopound.$

(b) $C_xH_y + \left(x + \frac{y}{4}\right) Q_2 \longrightarrow xCO_2 + \frac{y}{2} H_2O$

(c) (i) $Oxygen\ gas\ (O_2)$

(ii) $Carbon\ dioxide\ gas\ (CO_2)$

(iii) $10cm^3$

(iv) $20cm^3$

(d) $C_xH_y + \left(x + \frac{y}{4}\right) O_2 \longrightarrow xCO_2 + \frac{y}{2} H_2O$

$10cm^3 \quad 20cm^3 \quad \longrightarrow \quad 10cm^3$

$1mol\ of\ C_xH_y\ gives\ 1mol\ of\ CO_2\ , hence$

$x = 1$

$1mol\ of\ C_xH_y\ \ reacts\ with\ 2\ mol\ of\ O_2 or\ \left(x + \frac{y}{4}\right) = 2, hence\ y = 4$

$\therefore\ molecular\ formula\ of\ A = CH_4\ (CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$

(d) For gaseous hydrocarbons their number of moles are directly proportional to their volumes V∝n, hence their volumes are directly ratioed as their moles.

Solution 6

(a) $K_c = \frac{[CH_3CO_2R][H_2O]}{[CH_3CO_2R][ROH]},$ $\quad no\ units$

(c)

$K_c = \frac{[CH_3CO_2R][H_2O]}{[CH_3CO_2R][ROH]}$

$units: \frac{[mol/dm^3][mol/dm^3]}{[mol/dm^3][mol/dm^3]}$

= 1

Therefore no units.

(b) (i) $Moles\ of\ NaOH = Cone. of\ NaOH \times Volume\ of\ NaOH\ (indm^3)$

$$2.00 \times \frac{22.5}{1000} = 0.045\ moles$$

(ii) $NaOH\ is\ a\ monoacidic\ base, HCl\ is\ a\ monobasic\ acid.$

$Hence,$

$moles\ of\ NaOH\ reacted\ with\ HCl = moles\ of\ HCl = 0.005\ moles.$

$(iii)\ CH_3COOH + NaOH \longrightarrow CH_3COONa + H_2O$

$(iv)\ Moles\ of\ NaOH\ that\ reacted\ with\ ethonoic\ acid$

$= Moles\ of\ NaOH\ used\ in\ titration - Moles\ of\ NaOH\ that\ reacted\ with\ HCl$

$= 0.045 - 0.005 = 0.04\ moles$

$(c)\quad (i)\ From\ equation\ in\ part\ (b)(iii),$

$NaOH\ and\ ethanoic\ acid\ are\ reacting\ in\ ratio\ 1:1$

(c) (i) Moles of ROH (where R is Na in this case) and CH_3CO_2H and
at equilibrium are 0.04. Therefore moles

CH_3CO_2R and H_2O are 0.1 – 0.04 = 0.06 mol.

$Therefore, using\ the\ answer\ from\ part\ (b)(iv), we\ have,$

	CH_3CO_2H	ROH	CH_3CO_2R	H_2O
$initial\ amount/\ mol$	0.10	0.10	0	0
$equilibrium\ amount/mol$	0.04	0.04	0.06	0.06

$(i)\quad K_c = \frac{[CH_3CO_2R][H_2O]}{[CH_3CO_2R][ROH]} = \frac{0.06\times0.06}{0.04\times0.04} = 2.25$

$(d)\quad The\ activation\ energy\ required\ for\ the\ reaction\ between\ NaOH\ and\ an\ ester\ is\ high. Thus\ NaOH\ does\ not\ react\ with\ the\ ester.$

$(e)\quad According\ to\ Le\ Chatelier's priciple, to\ restore\ system\ to\ equalibrium, that\ side\ of the\ reaction\ would\ be\ favoured\ which\ produces\ more\ amount\ of\ water.\ Hence\ the\ equilibrium\ will\ shift\ towards\ the\ righty\ hand\ side\ and\ more\ ester\ would\ be\ produced.$

Solution 7

$(c)\quad (i)\ Mass\ of\ carbon\ present\ in\ 0.352\ g\ of\ CO_2$

$= \frac{molecular\ mass\ of\ carbon\ in CO_2}{M_r of\ CO_2} \times (mass\ of\ CO_2\ collected)$

$= \frac{12}{12+(16\times2)} \times 0.352 = 0.096g$

$moles\ of\ carbon\ present\ in\ A = \frac{mass\ of\ carbon\ in\ A}{A\ of\ carbon}$

$$= \frac{0.096}{12} = 0.008\, moles$$

(ii) $Mass\ of\ hydrogen\ present\ in\ 0.144g\ of\ H_2O$

$$= \frac{molecular\ mass\ of\ hydrogen\ in\ H_2O}{M_r of H_2O} \times mass\ of\ H_2O\ collected$$

$$= \frac{2\times1}{(1\times2)+16} \times 0.144 = 0.016g$$

$$moles\ of\ hydrogen\ prsent\ in\ A = \frac{mass\ of\ hydrogen\ in\ A}{A_r}$$

$$= \frac{0.016}{1} = 0.016\, moles$$

(iii) $mass\ of\ A = mass\ of\ oxygen\ in\ A + mass\ of\ hydrogen\ in\ A$

$$+ mass\ of\ carbon\ in\ A$$

$$\Longrightarrow\ 0.240 = mass\ of\ oxygen\ in\ A + 0.016 + 0.096$$

$$\Longrightarrow\ mass\ of\ oxygen\ in\ A = 0.240 - 0.016 - 0.096$$

$$= 0.128\ g$$

$$moles\ oxygen\ present\ in\ A = \frac{mass\ of\ oxygen\ in\ A}{A_r ox\ oxygen}$$

$$= \frac{0.128}{16} = 0.008\, moles$$

(b) $Consider\ the\ number\ of\ moles\ of\ carbon, hydrogen, and\ oxygen\ present\ in\ A$

$Element$	C	H	O
$No. of\ moles$	0.008	0.016	0.008
$simple\ ratio$	$\frac{0.008}{0.008}$	$\frac{0.016}{0.008}$	$\frac{0.008}{0.008}$
	1	2	1

$\therefore Empirical\ formula\ of\ A = CH_2O$

(c) (i) $pV = nRT$

$$\Longrightarrow\ pV = \left(\frac{m}{M_r}\right)RT \qquad \left(sines\ n = \frac{m}{M_r}\right)$$

$$\Longrightarrow\ M_r = \frac{mRT}{pV}$$

$$= \frac{(0.148)(8.31)(273+60)}{(101\times10^9)(67.7\times10^{-3})}$$

$= 59.896 \approx 58.9$

$(ii)\ n = \frac{molar\ mass}{empirical\ formula\ mass}$

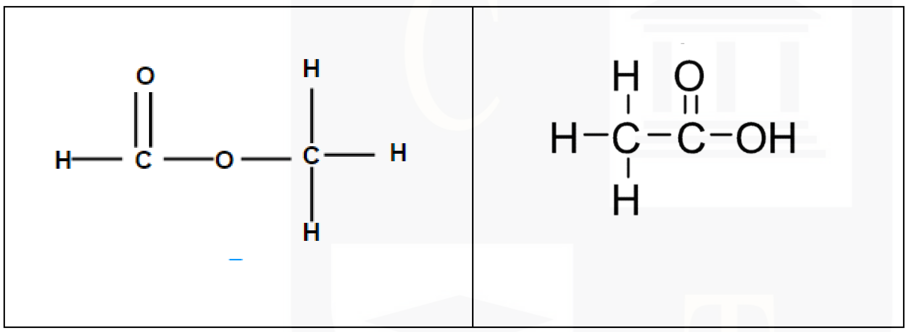
$= \frac{59.896}{12+2+16}$

$= \frac{59.896}{30} = 1.996 \approx 2$

$\therefore\ Molecular\ formula\ of\ A = C_nH_{2n}O_n$

$= C_2H_4O_2$

(d)



(e) *The only products of the reation are copper and two oxides,* H_2O *and* CO_2

Hence compound A contains only carbon, hydrogen and oxygen.

***Solution* 8**

(c) $ZnCO_3$ *and* $Zn(OH)_2$

(b) (i) *This done to ensure that all of the water of crystallization wa driven off and a constant mass of the tube and salt was obtained.*

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

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

$\therefore$ *number of moles of anhydrous* $ZnSO_4 + \frac{2.09}{161.5}$

$0.01294 \approx 1.29 \times 10^{-2} moles.$

(iii) *mass of* H_2O *driven off* $= 77.97 - 76.34 = 1.63g$

$M_r of\ H_2O = (1 \times 2) + 16 = 18$

$\therefore \quad number\ of\ moles\ of\ H_2O\ driven\ off = \frac{1.63}{18}$

$= 0.09055 \approx 9.1 \times 10^{-2}$

$(iv)\ \ in\ 1.29 \times 10^{-2}\ mol\ of\ ZnSO_4, number\ of\ mole\ of\ of\ H_2O\ driven\ off = 9.1 \times 10^{-2}$

$in\ 1\ mol\ of\ ZnSO_4, number\ of\ mol\ of H_2O\ driven\ off = \frac{9.1 \times 10^{-2}}{1.29 \times 10^{-2}}$

$= 7.054 \approx 7\ mol$

$Thus, the\ value\ of\ x = 7$

$(c)\ \ (i)\ \ Number\ of\ moles\ of\ zinc\ in\ 15\ mg\ of\ zinc = \frac{0.015}{65.4}$

$= 2.294 \times 10^{-4} \approx 2.29 \times 10^{-4} mol.$

$As\ the\ number\ of\ moles\ of\ zinc = number\ of\ moles\ of\ zinc\ ethancate,$

$hence, the\ mass\ of\ pure\ crystalline\ zinc\ ethancate\ required$

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

$= 0.05024g$

$= 0.05g = 50mg$

$(ii)\ \ Volume\ of\ aqueous\ zinc\ ehanoate = 5cm^3 = 0.005cm^3$

$concentration\ of\ solution = \frac{2.29 \times 10^{-4}}{0.005}$

$= 0.0458 = 4.58 \times 10^{-2}\ mol/dm^3$

Solution 9

$(b)\quad (i)\ \ 5Fe^{2+} + MnO_4^- + 8H^+ \longrightarrow\ Mn^{2+} + 4H_2O + 5Fe^{3+}$

$(ii)\ \ 5:1$

$(iii)\ \ MnO_4^- = 0.02 \times \frac{15}{1000} = 3 \times 10^{-4} mol.$

$(iv)\ \ Numer\ of\ moles\ of\ Fe^{2+} = 5(3 \times 10^{-4}) = 1.5 \times 10^{-3}\ mol.$

$(v)\ \ [Fe^{+2}]\ in\ partially\ used\ up\ solution = \frac{1.5 \times 10^{-3}}{2.5} \times 1000$

$= 0.6\ mol/dm^3$

(c) (i) *An oxidizing agent is a substance that gains electrons in a chemical reaction.*

(ii) *element*	Ba	Cl	O
$\%$ *by mass*	45.1	23.4	31.5
At	137	35.5	16
no of moles	$= \frac{45.1}{137}$	$\frac{23.4}{35.5}$	$\frac{31.5}{16}$
	$= 0.329$	0.659	1.698
Simple ratio	$= \frac{0.329}{0.329}$	$\frac{0.659}{0.329}$	$\frac{1.698}{0.329}$
	1	2	6

$empirical\ formula\ of\ A = BaCl_2O_6$

(vi) $Moles\ of\ Fe^{3+} in\ original\ solution\ of\ 100cm^3 = 1.50 \times \frac{100}{1000} = 1.15\ moles$

$moles\ of\ Fe^{2+}\ in\ partially\ used\ solution = 0.6 \times \frac{100}{1000} = 0.06\ moles$

$\therefore\ \ remaining\ moles\ of Fe^{3+} = 0.15 - 0.06 = 0.09\ moles$

$since, Fe^{3+} : Cu :: 2 : 1,$

$\therefore\ \ 0.09\ moles\ of\ Fe^{3+}\ can\ react\ with\ \frac{0.09}{2} = 0.045\ moles\ of\ Cu$

$mass\ of\ copper\ that\ could\ stillbe\ dissolved\ in\ 100Fe^{3+}\ of\ partially\ used\ up$ $solution = 0.045\ \times 63.5 = 2.86\ g$

Solution 10

(a) (i) $Number\ of\ moles\ of\ H_2SO_4 = \frac{25}{1000} \times 1.00 = 0.025\ moles.$

(ii) $Number\ of\ moles\ of\ NaOH = \frac{16.2}{1000} \times 2.00 = 0.0324\ moles.$

(iii) $NaOH\ and\ H_2SO_4\ react\ in\ the\ molar\ ratio\ 2 : 1$

$\therefore\ \ Number\ of\ moles\ of\ H_2SO_4\ that\ reacted = \frac{0.0324}{2} = 0.0162\ moles$

(iv) $Moles\ of\ H_2SO_4\ that\ reacted\ with\ NH_3 = 0.025 - 0.0162$

$= 0.0088\ moles$

(v) $NH_3\ and\ H_2SO_4\ react\ in\ the\ molar\ ratio\ 2 : 1$

$\therefore\ \ Moles\ of\ NH_3\ \ that\ reacted\ with\ H_2SO_4 = 2 \times 0.0088$

$= 0.0176\ moles$

(vi) $From\ given\ equation,$

$3\ moles\ of\ NaNO_3\ produce\ 3\ moles\ of\ NH_3$

$Hence\ number\ of\ moles\ of\ NH_3\ = 0.0176\ moles.$

$(vii)\ Mass\ of\ NaNO_3\ = number\ of\ moles\ of\ NaNO_3\ \times Mr\ of\ NaNO_3$

$= 0.0176 \times (23 + 14 + (16 \times 3))$

$= 0.0176 \times 85 = 1.496g$

$(viii)\ Percentage\ by\ mass\ of\ NaNO_3 = \frac{1.496}{1.64} \times 100$

$= 91.2\%$

(c) in $NaNO_3$ let the oxidation number of N be n (+1) +n + (3× (-2)) = 0

∴ n = + 5

In NH_3 let the oxidation number of N by y

Y + (3 × (+1)) = 0

∴ y = -3

$(b)\ NaNO_3 :\ +5\ \ and\ \ \ NH_3 :\ -3$

Solution 11

(a) *The nucleon number is the total number of protons and neutrons in the nucleus of an atom.*

(b) (i) *The relative isotopic mass of an isotope is the mass of an atom of the isotope compared to* $\frac{1}{12}$ *of the mass of a carbon* $- 12$ *atom.*

(ii) *Let the percentage abundance of* ^{79}Br *be* $x\%$

$\Longrightarrow$ *percentage abundance of* $^{81}\text{Br} = (100 - x)\%$

$$\therefore\ \left(78.92 \times \frac{x}{100}\right) + \left(80.92 \times \frac{100-x}{100}\right) = 79.9$$

$$0.7892x + 80.92 - 0.8092x = 79.9$$

$$x = 51$$

$\therefore$ *relative isotopc abundance of* $^{79}\text{Br} = 51\%$

relative isotopic abundance of $^{81}\text{Br} = 49\%$

(c) *Element*	A		Br
Mass	4.31		95.69
Molar Ratio	$\frac{4.31}{A_r}$	:	$\frac{95.69}{79.9}$

As the empirical formula of the compound is ABr_3, *the molar ratio must be equal to* $1 : 3$.

$$\frac{4.31}{A_r} : \frac{95.69}{79.9} = 1 : 3$$

$$\Longrightarrow\ \frac{4.31}{A_r} = \frac{1}{3} \times \frac{95.69}{79.9}\ \ \Longrightarrow\ \frac{4.31}{A_r} = 0.39921\ \ \Longrightarrow A_r = 10.796 \approx 10.8$$

Solution 12

(a) (i) *Oxidation is the loss of electrons. In the given sentence, the term oxidise means that ethanedioate ions lose electrons.*

(ii) $2MnO_4^-$(aq) $+ 5C_2O_4^{2-}$(aq)$+$ $\underset{\dots\dots\dots}{16}$ $H^+(aq) \rightarrow$ $\underset{\dots\dots\dots}{2Mgn^{2+}}$ $(aq) + 10CO_2(aq) +$ $\underset{\dots\dots\dots}{8}$ $H_2O(I)$

(b) (i) $Moles\ of\ manganate(VII) = 0.1 \times \frac{20}{1000} = 2 \times 10^{-3}\ moles.$

(ii) MnO_4^- *and* $C_2O_4^{2-}$ *are in the molar ratio* $2 : 5$

$\therefore\ moles\ of\ C_2O_4^{2-} = \frac{5}{2} \times 2 \times 10^{-3} = 5 \times 10^{-3}\ moles$

(iii) $Number\ of\ moles = 5 \times 10^{-3} \times \frac{250}{25} = 0.05\ moles$

(iv) $Relative\ formula\ mass, M_r = \frac{mass\ in\ grams}{number\ of\ moles} = \frac{6.30}{0.05} = 126.$

(v) $M_r\ of\ H_2C_2O_4 = 90,$ $\qquad M_r\ of\ H_2O = 18$

$\therefore\ 90 + 18x = 126$

$18x = 36 \implies x = 2$

Solution 13

(b) (i) $1s^2 2s^2 2p^6\ \ 3s^2 3p^6 3d^{10} 4s^2 4p^6 5s^2$

(ii) *Because strontium has four isotopes.*

(iii) $A_r = \left(84 \times \frac{0.56}{100}\right) + \left(86 \times \frac{9.86}{100}\right) + \left(87 \times \frac{7}{100}\right) + \left(88 \times \frac{82.58}{100}\right)$

$= 0.4704 + 8.4796 + 6.09 + 72.6704 = 87.7104 \approx 87.7$

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