VICTORIAN
VCE CHEMISTRY
1990

DETAILED SUGGESTED SOLUTIONS

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SUGGESTED SOLUTIONS

SECTION A
Question 1

Item 1ANS D
Element J is fluorine which forms an ion with one negative charge. Element Q is calcium which forms an ion with two positive charges. Hence, the formula is CaF_2 or QJ_2.

Item 2ANS A
The element with 6 protons in the nucleus is carbon (the number of neutrons is irrelevant). Carbon is column IV, row II. This is element E from the list.

Item 3 ANS B
Elements D and X are both in column I. Therefore, they are in the same group of the Periodic Table and have the same outershell electronic configuration but not identical electronic configurations. They will, however, exhibit similar chemical properties. The elements are lithium and rubidium.

Item 4 ANS C
Element R is a transition element. It is the element chromium. It has an incomplete 3d subshell.

Item 5 ANS D
The element R (chromium) is the only transition element in the list. One of the characteristics of transition elements is that they frequently form coloured compounds.

Item 6 ANS D
This is a nuclear equation which must be balanced both by charge and mass. The number of positive charges on the left hand side is 92. Likewise the number of positive charges on the right hand side = 36 + 56 = 92. Hence, the X particles have no charge. Therefore, they must be neutrons. As a check, 235 + 1 = 91 + 142 + (3x1) = 236. The X particles have 1 mass unit each.

Item 7 ANS B
The neutron on the left hand side of the equation splits the uranium nucleus into two parts. This is called nuclear fission. The energy released is equal to the difference between the binding energies of the products and the reactants. C would be true only if the uranium 235 were completely broken down into protons and neutrons.

Item 8 ANS D

2.00 moles of CO_2 has a mass of 88.0 g and a volume greater than 44.8 dm^3 since the temperature is greater than STP. 2.00 moles of CO_2 contains 2 x 6.02 x 10^{23} molecules. In each molecule of carbon dioxide, there are 3 atoms. The number of atoms in 2.00 moles of carbon dioxide is 3 x 2 x 6.02 x 10^{23} = 3.61 x 10^{24} atoms.

Item 9 ANS B

n(tetraethyl lead) = n(lead) = 0.40/207.2
Hence, m(tetraethyl lead) = (0.40/207.2) x (207.2 + (8x12) + 20x1))
= (0.40/207.2) x 323.2
= 0.624 g

Item 10 ANS C

n(Cl) in 100 cm^3 = n(NaClO) = 5.25/(23+35.5+16) = 5.25/74.5
n(Cl) in 750 cm3 = 7.5 x (5.25/74.5)
= 0.529

Item 11 ANS D

Let the relative atomic mass of the element be X.Let the mass of the element be m.
n(element) = m/X = PV/RT
Therefore, X = mRT/PV = 1.63 x 8.31 x 298/101.3 x 10^3 x 1.0 x 10^{-3}
= 39.8 which rounds off to 40.

Item 12 ANS D

n(C) = 42.0/12 = 3.5
n(H) = 5.3/1 = 5.3
n(N) = 24.6/14 = 1.8
n(O) = 28.1/16 = 1.8
To obtain the simplest whole number ratio, divide each of these by 1.8, and obtain the values 1.94 , 2.94 , 1 , 1 which rounded off give 2 , 3 , 1 , 1 and therefore, the empirical formula C_2H_3NO.

Item 13 ANS C

The equation for the reaction is $NaOH(aq) + HNO_3(aq) = NaNO_3(aq) + H_2O(l)$. The nitric acid is in excess by 0.2 x 0.002 mole = 0.0004 mole.
The concentration of hydrogen ions in the resulting solution is 0.0004/0.4. This equals 0.001 mole or 10^{-3} The pH is the negative log of this number. This equals 3.

Item 14 ANS A

The brown colour will fade when the first reaction is forced to the right. This will happpen if one of the products is removed. The H^+ ions will be removed by the addition of NaOH in the reaction $H^+(aq) + OH^-(aq) = H_2O(l)$. The addition of HCl is the addition of H^+. The addition of NaBr is the addition of Br^-. Both of these will force the reaction to the left and increase the intensity of the brown colour.

Item 15 ANS C
The production of sodium by electrolysis requires a molten electrolyte because water is more easily reduced than any sodium compound. The sodium is produced at the negative electrode (the sodium ion is Na^+) and the chlorine is produced at the positive electrode (the chloride ion is Cl^-).

Item 16 ANS A
In the electrolytic production of aluminium, the electrolyte is aluminium oxide (alumina) dissolved in molten cryolite. The anode (positive electrode) is carbon which is gradually used up during the process according to the equation:

$$C(s) + 2O^{2-} = CO_2 + 4e^-$$

Item 17 ANS A
The reaction of ammonia with oxygen tends to produce nitrogen gas rather than nitrogen monoxide gas under normal circumstances. However, by using a catalyst of a platinum-rhodium alloy, the production of NO is favoured. This is the main reason for the catalyst in this reaction.

Item 18 ANS D
The E^0 value for the silver half-cell is +0.80V. The E^0 value for the copper half-cell is +0.34V. The E^0 value for the zinc half-cell is -0.76V. The strongest reductant is the zinc metal and the strongest oxidant is the silver ion. The voltmeter will register the greatest possible potential difference. This is between the silver half-cell and the zinc half-cell. This equals +0.80 - (-0.76) = 1.56V.

Item 19 ANS B
The potential developed by the cell = E^0(oxidant) - E^0(reductant)
= 0.09 - (-1.25) = 1.34 V.

Item 20 ANS A
The positive electrode of the battery is the one at which electrons are being accepted. HgO is a stronger oxidant (electron acceptor) than $Zn(OH)_2$. Hence, the reaction is A.

Item 21 ANS C
A half-cell always consists of the oxidant and the reductant in the half-cell equation. For this half-cell, the metal would be Fe. The standard temperature is 298K.

Item 22 ANS D
NaOH is a strong base and will itself react with the skin. It must not be used. The best action is to use a weak base such as sodium bicarbonate solution to neutralise the acid or, if this is not available, water.

Item 23 ANS C
Perspex is formed by addition polymerisation in which a carbon-carbon double bond breaks down during the formation of the polymer. No such double bond exists in A.
B is not possible since the first carbon has five bonds. D is not possible since the first carbon has only three bonds. C is the correct monomer. Alternatively, this answer can be reached by observing that the empirical formula of the monomer must be the same as the empirical formula of the polymer.

Item 24 ANS D
Pentane has the molecular formula C_5H_{12}. An isomer of pentane must have the same molecular formula even though the arrangement of the atoms is different. **D** has the molecular formula C_5H_{10}. It is not an isomer of pentane even though it is called cyclopentane.

Item 25 ANS A
Calcium carbonate is formed initially according to the equation:
$Ca(OH)_2(aq) + CO_2(g) = CaCO_3(s) + H_2O(l)$

Item 26 ANS B
The carbon dioxide eventually reacts with the calcium carbonate to produce the soluble calcium hydrogen carbonate according to the equation:
$CaCO_3(s) + CO_2(g) + H_2O(l) = Ca(HCO_3)_2(aq)$

Item 27 ANS C
Silicon dioxide,SiO_2, is sand and obviously this is not a gas at room temperature.

Item 28 ANS D
The reaction of phosphorus with excess air is:
$$P_4(s) + 5O_2(g) = P_4O_{10}(s)$$
This is the molecular formula of the product. P_2O_5 is the empirical formula.

Item 29 ANS E
In reaction I, nitrogen changes oxidation number from -3 to +5. This is oxidation. In reaction II, nitrogen changes oxidation number from +5 to 0. This is reduction.

Item 30 ANS D
The structure of DNA consists of a backbone of **alternating** sugar and phosphate units with nitrogen bases attached to the **sugar** units. Two of these strands are held together by hydrogen bonding between the **nitrogen bases**. Adenine is bonded to thymine and cytosine is bonded to guanine

Item 31 ANS C
The oxidation states of nitrogen are -3 in NH_4Cl which contains the ion NH_4^+, +3 in $NaNO_2$ which contains the ion NO_2^- and 0 in N_2. Note that in any element, the oxidation state is zero. Nitrogen has been both oxidised and reduced in this reaction.

Item 32 ANS D
In this reaction, the nitric acid oxidises iron(II) to iron(III) and also neutralises the hydroxide ions to form water. Hence, it is acting as both an oxidising agent and an acid.

Item 33 ANS A
A galvanic cell is set up between the steel (Fe) and the tin. The steel is oxidised to iron(II) and iron(III) as electrons move from the steel to the tin. Hence, the tin acts as the positive electrode.

Item 34 ANS B
Sulfur is a solid under normal conditions of temperature and pressure. It is not found as free sulfur in the atmosphere. It can occur in the atmosphere in a compounds such as sulfur dioxide.

Item 35 ANS A
The equilibrium constant $K_c = [SO_3]^2/[SO_2]^2.[O_2]$
$= (2.2 \times 10^{-3})^2/((7.2 \times 10^{-6})^2 \times 6.3 \times 10^{-3})$
$= 1.5 \times 10^7$

Item 36 ANS B
The mineral in copper ore is present only in small amounts and must be concentrated before being refined. This is done by froth flotation.

Item 37 ANS C
Ozone is a secondary pollutant in photochemical smog. It is produced from the reaction between nitrogen oxides and hydrocarbons in the presence of sunlight.

SECTION B
Question 2
a.
Carbon (C) , column IV, row II.
Nitrogen (N) , column V , row II.
Oxygen (O) , column VI , row II.
Phosphorus (P) , column V , row III.
Sulfur (S) , column VI , row III.
Silicon (Si) , column IV , row III.
Sodium (Na) , column I , row III. ONE POSSIBLE EXAMPLE
Magnesium (Mg) , column II , row III. ONE POSSIBLE EXAMPLE

b. i.
In a particular iodine atom, there are 53 protons and a total of 127 protons + neutrons. Therefore, there are 74 neutrons in this isotope of iodine.

b ii.
The elements in the modern Periodic Table are arranged in order of increasing atomic number; that is, in order of the number of protons in the nucleus. When this is done, it is found that elements which exhibit similar chemical properties are in the same group of the Table. It should be noted that historically, elements were placed in groups showing similar chemical properties before anything was known about the internal structure of the atom.

b iii.
The element tellurium must have an atomic number of 52 since it is one place BEFORE iodine. It can also be said that the element tellurium must have naturally occurring isotopes with larger numbers of neutrons than iodine since the releative atomic mass of tellurium is greater than the relative atomic mass of iodine.

Question 3

a.

$$C_6H_6Cl_6(l) + 6O_2(g) = 6CO_2(g) + 6HCl(g)$$

b.

$$AgNO_3(aq) + HCl(aq) = AgCl(s) + HNO_3(aq)$$

or

$$Ag^+(aq) + Cl^-(aq) = AgCl(s)$$

c.

$n(AgNO_3) = n(AgCl) = 2.32/(107.9+35.5) = 0.016$

The original amount of AgNO3 = 0.25 x 0.2 = 0.05 mole. This is more than required to precipitate all of the Cl.

d.

n(Cl) in sample = n(Cl) in precipitate = n(AgCl) = 0.016

e.

$n(C_6H_6Cl_6) = (1/6) \times n(Cl) = (1/6) \times 0.016$

Hence, $m(C_6H_6Cl_6) = (1/6) \times 0.016 \times (72 + 6 + 213) = (1/6) \times 0.016 \times 291 = 0.776g$

Therefore, % purity of the insecticide = (0.776/1) x 100 = 77.6%

If the solution to the previous question (0.016) is not rounded off, the percentage is calculated as 78.46%.

An appropriate solution to the problem would be 78% since the concentration of the silver nitrate is only given to 2 significant figures (0.2M).

f.

The original wet precipitate would contain silver nitrate in solution. If the precipitate were not washed with distilled water before drying, the dry precipitate would contain solid silver nitrate and the mass of the precipitate would be greater than the true value.

Question 4

a.

The reaction at the positive electrode is $Cu(s) = Cu^{2+}(aq) + 2e^-$. The number of mole of electrons used, $n(e^-) = 2 \times n(Cu)$ reacting $= 2 \times 0.393/63.5$. The quantity of electricity used = current x time = 1.4 x 12 x 60 coulombs. The charge on one electron is 1.6×10^{-19} coulombs. Hence, the number of electrons used in this experiment is equal to $1.4 \times 12 \times 60/1.6 \times 10^{-19}$. Hence, the Avogadro Constant (N_A), the number of electrons in one mole is given by $(1.4 \times 12 \times 60)/(1.6 \times 10^{-19} \times 2 \times 0.393/63.5)$. This equals 5.1×10^{23}. Notice that this value has been experimentally determined and is not the same as the accepted value of the Avogadro Constant. You cannot simply divide 96500 by 1.6×10^{-19} to obtain the 'correct' value of 6.0×10^{23}!

ANS = 5.1×10^{23}

Question 4 (continued)
b. i. ii.
Cu^{2+} (+0.34V) is a stronger oxidant than H_20 (-0.83V) and Cu (+0.34V) is a stronger reductant than H_2O (1.23V)
At the beginning, the reactions are:
A(positive electrode): $Cu(s) = Cu^{2+}(aq) + 2e^-$
B(negative electrode): $Cu^{2+}(aq) + 2e^- = Cu(s)$.
As the voltage is increased, the water will react first at the positive electrode (A) to form oxygen according to the equation: $2H_2O(l) = O_2(g) + 4H^+(aq) + 4e^-$
Only when the concentration of copper(II) ions in the solution has decreased to a very low value will hydrogen be produced at the negative electrode.

Question 5

a.
(1) This chemical process is photosynthesis.
(2) This reaction occurs in green plants.
(3) This reaction is endothermic (energy is stored in the products)

b.
(1) Water is changed from liquid to gas by the power station furnace.
(2) The reaction is endothermic (energy is stored in the products).
(3) The water is gaseous form is used to spin the turbines to generate the electricity.

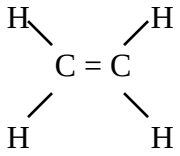
c.
(1) The burning of the coal (carbon) occurs in the power station furnace.
(2) This reaction is exothermic (heat is released).

d.
(1) This is a nuclear fusion reaction and occurs in the sun.
(2) This reaction is exothermic (energy is released).

e.
(1) Coal contains sulfur and when the coal is burnt, the sulfur is burnt and sulfur dioxide is produced. This occurs in the power station furnace.
(2) Sulfur dioxide is a pollutant in the atmosphere since it contributes to the acidity of rainwater and is harmful to both plants and animals.

Question 6

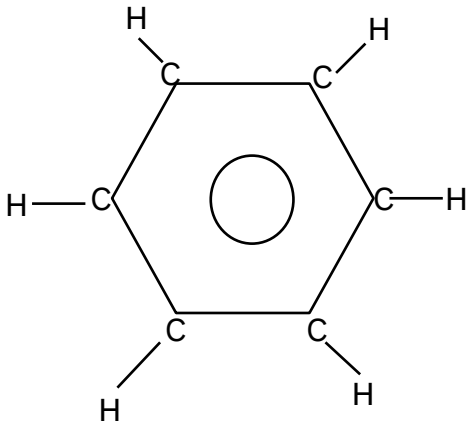
a.

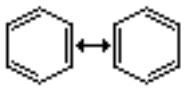


The molecular formula is C_2H_4.The bond angles in ethylene are 120^o

The molecule is planar with the atoms arranged in the shape of an equilateral triangle around each carbon atom.

b.





Kekule Structure

Benzene has the molecular formula C_6H_6. It has the shape of a regular hexagon with one hydrogen atom attached to each carbon atom. There are six delocalised electrons which are shared by all six carbon atoms. The bond angles are 120^o. The molecule is planar.

c.

i. Alkenes typically undergo addition reactions.

A typical addition reaction for ethylene is the formation of chloroethane:

$C_2H_4(g) + HCl(g) = C_2H_5Cl(g)$

ii. Benzene typically undergoes substitution reactions.

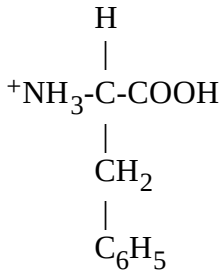
A typical substitution reaction for benzene is the formation of nitrobenzene:

$C_6H_6(l) + NO_2^+ = C_6H_5NO_2(l) + H^+$

Question 7

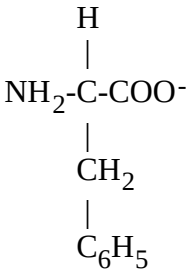
a. i.

A solution of low pH is an acidic solution. The basic end of the amino acid reacts to produce NH_3^+ on one end of the molecule.



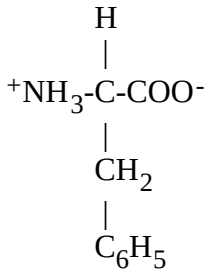
ii.

A solution of high pH is a basic solution. The acidic end of the amino acid reacts to produce COO^- on one end of the molecule.



iii.

The amino acid reacts with itself in an acid-base reaction to produce NH_3^+ and COO^- on the ends of the molecule.



b.

Enzymes are proteins which act as specific catalysts for particular chemical reactions. They enable reactions to occur with precision and at much lower temperatures than would otherwise be possible.

Question 8

a.

$$AgCl(s) + 2NH_3(aq) = Ag(NH_3)_2^+(aq) + Cl^-(aq)$$

b.

$$NH_3(aq) + H_2O(l) = NH_4^+(aq) + OH^-(aq)$$

then $Cu^{2+}(aq) + 2OH^-(aq) = Cu(OH)_2(s)$

c.

$$Cu(OH)_2(s) + 4NH_3(aq) = Cu(NH_3)_4^{2+}(aq) + 2OH^-(aq)$$

d.

The brown gas is nitrogen dioxide.

$$4NH_3(g) + 7O_2(g) = 4NO_2(g) + 6H_2O(l)$$

e.

$$2NO_2(g) = N_2O_4(g)$$

Question 9

a.
Coke is added to the blast furnace to produce carbon monoxide (which is the reducing agent for the iron oxide) according to the equation: $2C(s) + O_2(g) = 2CO(g)$. The combustion of the coke provides the heat to melt the iron. Also the coke carries out the physical function of keeping the contents of the furnace porous so that the gases can move freely.

b.
The limestone, calcium carbonate, is added to the blast furnace to act as a flux. It decomposes to calcium oxide which then reacts with several of the impurities to form a slag which floats on the molten iron and is easily removed. For example:
$CaCO_3(s) = CaO(s) + CO_2(g)$ and $CaO(s) + SiO_2(s) = CaSiO_3(s)$

c.

i. Mass of iron produced = $((2 \times 55.8)/159.6) \times (90/100) \times 100 \times 10^6$
$= 6.3 \times 10^7$ tonnes

ii. Number of mole of carbon dioxide = (3/2) x n(Fe)

Volume of carbon dioxide = nRT/P
$= (3/2) \times (6.3 \times 10^7 \times 10^6/55.8) \times 8.31 \times 573/110 \times 10^3$
$= 7.3 \times 10^{10}\ m^3$

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