NSMQ PAST QUESTIONS; CHEMISTRY (03)

Preamble to all schools:

Consider the following elements, listed not in any particular order.

Beryllium, Argon, Silicon, and Sodium.

1. Which of these elements has the lowest first ionization energy?

   Ans: Sodium

2. Which of these elements has the biggest atomic radius?

   Ans: Argon

3. Which of these elements is most electronegative?

   Ans: Silicon

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1. Why was VALCO, the first aluminum smelter company in Ghana, sited at Tema in the Greater Accra Region.

   Ans: Sited at Tema so as to receive imported alumina through the Tema harbour and also having electricity supply from Akosombo.

2. Why is the electrolysis of molten alumina preferred to electrolysis of an aqueous solution of Al^{3+} ions in the commercial production of aluminum?

   Ans: H^+ ions in the aqueous solution will be discharged at the cathode in preference to the Al^{3+} ions OR the reduction potential of H^+ ions is higher than that of Al^{3+}.

3. Calculate the pH of 0.100 $moldm^{-3}$ solution of a sodium salt of an alkanoic acid whose pK_a is 4.80.

   Ans: pK_b of the conjugate base = 14.0 – 4.80 = 9.20

   pOH = ½ pK_b - ½ log C_b (C_b = 0.100 $moldm^{-3}$)

   = 9.20/2 + 0.500 = 5.10

   Hence pH = 14.0 - 5.10 = 8.90.

Preamble to all schools:

In the commercial preparation of trioxonitrate(V) acid, nitrogen(IV) oxide dissolves in water to give the acid while nitrogen(II) oxide is evolved. The balanced equation for the reaction is as follows:

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

O = 16.0; N = 14.0; H = 1.00. The molar volume of a gas at STP is 22.4dm^3.

1. Calculate the mass of HNO_3 that can be produced from 69.0g of NO_2 gas.

   Ans: $3NO_2 + H_2O \rightarrow 2HNO_3 + NO.$

   3 x 46.0 2 x 63.0

   138g of NO_2 ≡ 126g of HNO_3

Therefore, mass of HNO_3 to be produced from 69.0g of NO_2 = (69.0/138)*126g = 63.0g

2. Find the volume of NO_2 at STP that can be used to produce 189g of HNO_3.

   Ans: $3NO_2 + H_2O \rightarrow 2HNO_3 + NO$.

   Moles of HNO_3 in 189g of it. = 189/63.0 = 3.00

   Moles of NO_2 needed = (3.00/2.00)*3 = 4.50.

   Hence volume of NO_2 at STP required = 4.50*22.4 = 100.8dm^3 = 101dm^3

3. Calculate the mass of the minimum amount of water required to react completely with 44.8 dm^3 of NO_2 at STP.

   Ans: $3NO_2 + H_2O \rightarrow 2HNO_3 + NO$.

   Moles of NO_2 in 44.8dm^3 of the gas at STP = 44.8/22.4 = 2.00

   Moles of water required = (1/3)*2 = 2/3

   Mass of water = (2/3)*18.0 = 12.0g

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1. Which element has atoms with bigger atomic radius, silicon, or aluminium?

   Ans: Aluminium

2. Which element is relatively more electropositive, sulphur or selenium?

   Ans: Selenium

3. Which element has the higher first ionization energy, hydrogen, or helium?

   Ans: Helium

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1. If the enthalpies of formation in $kJmol^{-1}$ of 1-pentyne, 1-pentene and pentane are +145, -21.0, and -147 respectively, calculate the enthalpy of hydrogenation of i) 1-pentyne to 1-pentene and ii) 1-pentene to pentane. Indicate which reaction is thermodynamically more favourable.

   Ans: 1-Pentyne → 1-pentene

   $\Delta r = \Sigma\Delta H_{products} - \Sigma\Delta H_{reactants} = -21.0 - (+145) = -166kJ$

   1-Pentene → pentane

   $\Delta r = \Sigma\Delta H_{products} - \Sigma\Delta H_{reactants} = -147 -(- 21.0) = -126kJ$

   The reduction from 1-pentyne to 1-pentene is thermodynamically more favourable.

2. If the enthalpies of formation in $kJmol^{-1}$ of 2-pentyne, cis-2-pentene and trans-2-pentene are +129, -28.1 and -31.9 respectively, calculate the enthalpy change for the reduction 2-pentyne to i) cis-2-pentene and ii) trans-2-pentene. Indicate which reaction is thermodynamically more favourable and give the reason for that relative order.

   Ans: 2-Pentyne → cis-2-pentene

   $\Delta r = -28.1 - (+129) = -157kJ$

   2-Pentyne → trans-2-pentene

   $\Delta r = -31.9 - (+129) = -161kJ$

Reduction to the trans compound is thermodynamically more favourable.

Reason: The trans compound is more stable/has lower internal energy

3. If the enthalpies of formation in $kJmol^{-1}$ of cis-2-pentene, trans-2-pentene and pentane are -28.1, -31.9 and -147 respectively, calculate the enthalpy change for the reduction i) cis-2-pentene to pentane and ii) trans-2-pentene to pentane. Indicate which reaction is thermodynamically more favourable and give the reason for that relative order.

Ans: cis-2-Pentene → pentane

Δr = -147 - (-28.1) = -119kJ

trans-2-Pentene → pentane

Δr = -147 - (-31.9) = -115kJ

Reduction of the cis compound is thermodynamically more favourable.

Reason: The cis compound is less stable/has higher internal energy.

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1. Define a base according to the Lewis concept:

Ans: A base is an **electron pair** donor.

2. Define an acid according to the Bronsted – Lowry concept

Ans: An acid is a **proton** donor.

3. What are the usual constituents of a buffer solution?

Ans: A buffer solution will usually contain a weak acid and its conjugate base or a weak base and its conjugate acid.

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1. If the half–life of a first order reaction is 2.00 minutes, calculate the rate constant of the reaction.

Ans: $t_{1/2}$ = 0.693/k

k = 0.693/2.00*60.0 = $5.78*10^{-3}\ s^{-1}$

2. The decay constant of a radioactive substance is $6.60*10^{-3}\ s^{-1}$. Calculate the half – life of the substance.

Ans: $t_{1/2}$ = 0.693/k

= $0.693/6.60*10^{-3}$ = 105 s or 1min 45s

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3. A radioactive substance has a half – life of 2.00 hours. What percentage of the initial activity will be left after 10.0 hours?

Ans: There are 5 half – lives in 10.0 hours.

0	-	2	-	4	-	6	-	8	-	10
		50%		25%		12.5%		6.25%		3.13

So, the percentage left is 3.13% of the initial activity.

1. The so-called batteries used in mobile phones are dry voltaic cells. What type of cells are they?

   Ans: Secondary Voltaic Cells – (they can be recharged after they have been discharged)

2. Consider the reversible reaction:

   $A_{(g)}$ + $3\ B_{(g)}$ + - heat $\rightleftharpoons$ $C_{(g)}$ + $D_{(g)}$

   At which of the following temperatures will the equilibrium constant be largest, 200^{o}C or 300^{o}C or 400^{o}C?

   Ans: 400^{o}C. (Le Chatelier's Principle)

3. Give the colour that a copper compound imparts to a colourless flame.

   Ans: Green

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1. Give the name of the first element and also the number of naturally occurring elements present in Group VI or 16 of the Periodic Table.

   Ans: Oxygen; Five (5) elements

2. What are the first and the last elements in Period 4?

   Ans: Potassium and Krypton

3. What is the atomic number of the last element in the first d–transition series?

   Ans: 30 (20 +10) (Zinc)

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1. An organic acid HA has a dissociation constant K_a of $4.00*10^{-9}$. Calculate the concentration of A^- ions in a 0.100 moldm^{-3} solution of the acid. Assume the amount of the acid that dissociates is negligible compared to its original concentration.

   Ans: $HA_{(aq)} \rightleftharpoons H^+_{(aq)} + A^-_{(aq)}$; But $[H^+_{(aq)}] = [A^-_{(aq)}]$

   $K_a = [A^-_{(aq)}]^2/[HA_{(aq)}]$

   $[A^-_{(aq)}] = [(4.00*10^{-9})(1.00*10^{-1})]^{½} = 2.00*10^{-5}$ moldm^{-3}

2. Calculate the pH of 0.100 $moldm^{-3}$ solution of the conjugate base of methanoic acid, if the pK_a of the acid is 3.76.

Ans: pK_a + pK_b(conjugate base) = 14.0

pK_b(Conjugate base) = 14.0 - 3.76 = 10.2

pOH = ½ pK_b - ½ log C_b = 5.10 + 0.500 = 5.60

Hence pH of solution of base = 14.0 - 5.60 = 8.40

3. If the pH of 0.100 $moldm^{-3}$ solution of a sodium alkanoate, NaX is 9.20, calculate the pK_a of the alkanoic acid HX.

Ans: pOH of the alkanoate solution = 14.0 - 9.20 = 4.80

But pOH = ½pK_b (alkanoate) - ½logC_b

Hence pK_b = 2*4.80 - 1.00 = 8.60

pK_a of alkanoic acid = 14.0 - 8.60 = 5.40

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1. What is the name of a saturated hydrocarbon with 12 carbons in a chain?

Ans: Dodecane.

2. Calculate the number of moles of limestone ($CaCO_3$) in a 2.00 kg gold ore that contains only 0.500% gold, the rest being $CaCO_3$ in the form of limestone.

Ca = 40.0; O = 16.0; C = 12.0

Ans: Mass of limestone = (2000 – 10.0) = 1990

Formula mass of limestone = 40.0 + 12.0 + 48.0 = 100

Moles of limestone = 1990/100 = 19.9 mol.

3. Which flask is needed to perform suction filtration in the laboratory?

Ans: (Heavy wall) filtering flask.

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1. Name the source of heating that will be used in the fractional distillation of two liquids whose boiling points are about 45°C and 55°C respectively.

Ans: Electric heating mantle OR

A water bath on (an electrically heated) hot plate OR.

A water bath heated with a Bunsen burner under an asbestos mat.

2. Name the piece of glassware that must be present in a set up for heating a liquid mixture under reflux.

Ans: (Water) Condenser

3. Name the piece of glassware suitable for preparation of a bulk solution of accurately known concentration.

   Ans: Volumetric Flask

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1. When solid $KMnO_4$ is heated K_2MnO_4, MnO_2 and oxygen gas are formed. Give a balanced equation for the reaction.

   Ans: $2\ KMnO_4 \rightarrow K_2MnO_4 + MnO_2 + O_{2(g)}$

2. What is the difference between hard water and heavy water?

   Ans: Hard water is water in which soap does not lather easily whilst heavy water is liquid D_2O or deuterium oxide.

3. Name the isomeric alkene or alkenes of 1-pentene that will show cis-trans isomerism.

   Ans: 2-Pentene

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1. $18.0 dm^3$ of nitrogen gas at a pressure of 120 kPa is compressed to a pressure of 160 kPa at a constant temperature. Calculate the new volume.

   Ans: $V_1 = 18.0\ dm^3$; $P_1 = 120$ kPa; $P_2 = 160$ kPa; $V_2 = ?$

   $P_1V_1 = P_2V_2$; $V_2 = (P_1/P_2)*V_1$

   $V_2 = (120/160)*18.0 = 13.5\ dm^3$

2. The volume of oxygen gas obtained in an experiment at 27^oC is $3.90\ dm^3$. What would have been the volume of the oxygen obtained if the room temperature had been 37^oC? Assume the pressure of the gas was constant.

   Ans: $V_1 = 3.90\ dm^3$; $T_1 = (27 + 273) = 300$

   $T_2 = (273 + 37) = 310$; $V_2 = ?$

   From Charles' law, $V_1/T_1 = V_2/T_2$; $V_2 = (T_2/T_1)*V_1$

   $V_2 = (310/300)*3.90 = 4.03 dm^3$.

3. A balloon contains $16.5 dm^3$ of neon at 27.0^oC and 100 kPa. If the gas is heated to 72.0^oC while the pressure in the balloon increases to 115 kPa, calculate the volume of the balloon under these conditions.

   Ans: Using the combined Boyle's and Charles' Laws

   $P_1V_1/T_1 = P_2V_2/T_2$; $V_2 = (P_1/P_2)*(T_2/T_1)*V_1$

   $P_1 = 100$ kPa; $P_2 = 115$ kPa;

$T_1 = (27.0 + 273) = 300$ K; $T_2 = (72.0 + 273) = 345$ K

$V_2 = (100/115)*(345/300)*16.5 = 16.5dm^3$.

Preamble to all schools

Consider the following reversible chemical reaction:

$A_{(g)} + 2B_{(g)} \rightleftharpoons 3C_{(g)}$; $\Delta Hr = -230kJ$

1. How will an increase in temperature affect the equilibrium constant?

   Ans: K_{eq} will decrease since the forward reaction is exothermic.

2. At equilibrium how will an increase in volume affect the equilibrium position?

   Ans: Since the number of gaseous reactant molecules are the same as the products the equilibrium position will not be affected by changes in volume.

3. How will an addition of a catalyst affect the equilibrium constant?

   Ans: The equilibrium constant will not be affected by the addition of a catalyst.

Preamble to all schools:

An organic compound A decomposes by second order kinetics. The integrated form of the second order rate equation is $1/[A_t] = kt + 1/[A_0]$, where $[A_0]$is the initial concentration of A and $[A_t]$is its concentration at time t.

1. Calculate the rate constant if 10.0% of the initial concentration of 0.100 $moldm^{-3}$ of A is decomposed after 50.0 seconds. Remember to give your answer in the standard or scientific form.

Ans: $1/[A_t] = kt + 1/[A_0]$

Concentration of A after 50.0 s = $0.0900moldm^{-3}$.

$1/0.0900 = k*50.0 + 1/0.100$; $11.1 = 50.0k + 10.0$

$k = 1.10/50.0 = 1.10/50.0 = 2.20*10^{-2}\ mol^{-1}dm^{3}s^{-1}$

2. Calculate the rate constant if in another reaction 60.0% of the 0.100 $moldm^{-3}$ of A had decomposed in 150 seconds. Give your answer in the standard form.

Ans: $1/[A_t] = kt + 1/[A_0]$

$1/0.0400 = k*150 + 1/0.100;$ $25.0 = 150k + 10.0$

$k = 15.0/150 = 1.00*10^{-1}\ mol^{-1}dm^3s^{-1}$

3. For another decomposition reaction of A, determine the time in seconds it takes 50.0% of the initial concentration of 0.100 $moldm^{-3}$ of A to decompose if the rate constant of that reaction is found to be $2.00*10^{-2}\ mol^{-1}dm^3s^{-1}$

   Ans: $1/[A_t] = kt + 1/[A_0]$

   $1/0.0500 = k*t + 1/0.100;$ $20.0 = 2.00*10^{-2}t + 10$

   $t = 10.0/2.00*10^{-2} = 500s$ (or 8min 20s)

   [<u>Alternative method</u>: Time for 50% of concentration to be consumed is $t_{½}$.

   But for a second order reaction, $t_{½} = 1/k[A_0]$

   $t_{½} = 1/2.00*10^{-2}*0.100 = 1.00*10^3/2 = 500s$]

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1. What is the name of the energy required to produce oxygen atoms from oxygen molecules at standard temperature and pressure?

   Ans: Standard enthalpy/heat of atomization.

   (Note: $½O_2 \rightarrow O$ atomization) ($O_2 \rightarrow 2O$ dissociation)

2. What do we call isomers that affect the plane of polarized light to the same extent but in the opposite direction?

   Ans: Enantiomers (Do not accept optical isomers.)

3. A metal M of atomic mass 51.0 forms an oxide containing 44.0% oxygen. What is the empirical formula of the metal? O = 16.0

   Ans: % Metal in the oxide = 100 - 44.0 = 56.0

<u>M</u>		<u>O</u>
56.0/51.0		44.0/16.0
1.10		2.75
1	:	2.50
2	:	5

   Empirical formula = M_2O_5

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1. Explain the process of 'Radioactive decay'.

   Ans: It is the spontaneous disintegration of a radioactive nucleus to give a daughter nucleus or daughter nuclei and radiation (or nuclear particles)

2. Some radioactive nuclei decay by α–emission. What is the process equivalent to?

Ans: It is a loss of atomic mass units of 4 and atomic number of 2 or loss of helium nucleus.

3. By what means can a non–radioactive nucleus be made to disintegrate.

Ans: By bombardment of the nucleus with (energetic) nuclear particles.

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1. Calculate the percent oxygen by mass in magnesium trioxocarbonate(IV).

Mg = 24.0 O = 16.0; C = 12.0

Ans: $MgCO_3$ = 24.0 + 12.0 + 48.0 = 84.0

%O = (48.0/84.0)*100 = 57.1%

2. Calculate the percent carbon by mass in sodium trioxocarbonate(IV).

Na = 23.0 O = 16.0; C = 12.0

Ans: Na_2CO_3 = 46.0 + 12.0 + 48.0 = 106

%C = (12.0/106)*100 = 11.3%

3. Calculate the percent calcium by mass in calcium trioxocarbonate(IV).

Ca = 40.0; O = 16.0; C = 12.0

Ans: $CaCO_3$ = 40.0 + 60.0 = 100

%Ca = (40.0/100)*100 = 40.0%

Preamble to questions (1) and (2).

Consider the reversible reaction given below:

$$2A_{(g)} + B_{(g)} \rightleftharpoons 2C_{(g)} + 3D_{(g)}$$

1. Give the expression for the K_c of the reaction when it is in equilibrium.

Ans: K_c = $[C]^2[D]^3/[A]^2[B]$

2. Give the relationship between the K_c and K_p of the reaction

Ans: K_p = $K_c(RT)^{\Delta n}$ where Δn is the difference in the number of gaseous products and gaseous reactants. Δn = 2

Therefore, $K_p = K_c(RT)^2$ OR $K_c = K_p(RT)^{-2}$

3. Give the products of decomposition when solid lithium trioxonitrate(V) is heated.

   Ans: Lithium oxide (Li_2O) and nitrogen(IV) oxide (NO_2)

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1. Give the difference between vapourisation and sublimation.

   Ans: **Vapourisation** refers to the change of a <u>solid</u> or <u>liquid</u> to the vapour/gaseous phase, but **Sublimation** refers specifically to change from <u>solid</u> to vapour/gaseous phase (without passing through the liquid phase)

2. What benefits are derived from the Kinetic Theory of gases.?

   Ans: It tries to explain the simple relationships among the physical properties of gases.

3. Name the four parameters or properties that are related in the Ideal Gas Law.

   Ans: Pressure (P), Volume (V), Temperature (T) and Molar quantities (n)

   (i.e. $PV = nRT$)

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1. 2.00 kg of bauxite after processing yields 714 g of alumina. What is the percentage aluminum in the bauxite assuming the processing does not lead to any loss of alumina?

   Al = 27.0, O = 16.0

   Ans: Alumina = Al_2O_3 = 54.0 + 48.0 = 102

   Mass of Al in 714g of alumina = (54.0/102)*714 = 378 g.

   %Al in bauxite = (378/2000)*100 = 18.9%

2. A gold bearing rock is found to contain $3.14*10^{-2}$ percent of gold. How many grams of gold can be obtained from 15.0 kg of the rock assuming the processing is 100% efficient?

   Ans: Mass in kg of gold in 100kg rock = $3.14*10^{-2}$ kg ≡ $(3.14*10^{-2}*10^3)$ g

   Mass in g of gold in 100kg rock = 31.4 g of gold

   Therefore, mass in g of gold in 15.0 kg of rock = (15.0/100)*31.4 = 4.71g.

3. Chromium may be obtained by reduction of its oxide Cr_2O_3 with carbon at high temperatures. If 760 g of impure oxide yields only 416 g of chromium, what is the percentage purity of the oxide?

Cr = 52.0; O = 16.0

Ans: Cr_2O_3 = 104 + 48.0 = 152; Hence 152 g of Cr_2O_3 ≡ 104 g Cr

Therefore, 760g of pure Cr_2O_3 ≡ (760/152)*104 = 520 g Cr

Therefore, % purity = (416/520)*100 = 80.0%

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1. Equal volumes of CO_2 and an unknown gas at the same temperature and pressure have masses of 5.50g and 4.00g, respectively. Determine the molar mass of the unknown gas.

   Ans Use the Avogadro's Hypothesis: Let the molar mass of the gas be M.

   Equal volumes at the same pressure and temperature contain the same number of moles,

   Moles of CO_2 = 5.50/44.0; Moles of unknown gas = 4.00/M

   Hence M = (44.0/5.50)*4.00 = 32.0

2. State the expected observation when an alkanoic acid is tested with $NaHCO_3$ solution and explain the chemistry of the test.

   Ans: Observation: Effervescence is observed

   Chemistry: The alkanoic acid protonates the HCO_3^- ion to give H_2CO_3 which decomposes to CO_2 gas and H_2O.

3. Name the metalloids in the fourth period of the Periodic Table.

   Ans: Germanium (Ge) and Arsenic (As).

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1. The sulphur content in petroleum products is an important factor in determining the quality of the products, why?

   Ans: High sulphur in a petroleum product translates into high SO_2 emissions. SO_2 corrodes metal parts and also causes acid rain.

2. Name one compound normally found in crude oil that may be the source of sulphur in a petroleum product.

Ans: i)Hydrogen sulphide or ii)sulphur(IV) oxide or iii) thiols(also known as mercaptans) or iv) thiophene or v) benzothiophene or vi) dibenzothiophenes.

3. What role does a Reforming Unit play in an oil refinery?

   Ans: It converts alkanes into alkenes and aromatic hydrocarbons which have higher octane numbers.

Consider the following bond energies all in $kJmol^{-1}$:

C – C 345; C = C 610; C – H 410; C – O 360; C = O 805; H – H 435; O – H 465.

1. Calculate the enthalpy change for formation of the necessary bonds in the reduction of 1-butene to butane by hydrogen gas.

   Ans: $CH_2{=}CHCH_2CH_3$ + H_2 → $CH_3{-}CH_2CH_2CH_3$

   Bonds formed = C–C and 2C–H; Enthalpy change = -345 + - 410*2

   = -1165 kJ or $-1.17*10^3$kJ

2. Calculate the energy required to beak the necessary bonds during the reduction of 1-butene to butane by hydrogen gas.

   Ans: $CH_2{=}CHCH_2CH_3$ + H_2 → $CH_3{-}CH_2CH_2CH_3$.

   Bonds broken = C=C and H_2; Energy required = 610 + 435

   = 1045 kJ or $1.05*10^3$kJ.

3. Calculate the enthalpy change for the formation of the necessary bonds in the reduction of propanone to 2-propanol with hydrogen gas

   Ans: CH_3COCH_3 + H_2 → $CH_3CHOHCH_3$

   Bonds formed = C–O, C–H and O–H

   Enthalpy change = -360 + (- 410) + (- 465) = -1235 or $-1.24*10^3$ kJ.

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1. Why is phenol acidic?

   Ans: The conjugate base/the phenoxide ion is stabilised by resonance.

2. Which of the following six graphs would not give a straight line for an Ideal Gas, other parameters remaining constant?

   i) V versus P; ii) T versus P; iii) V versus T; iv) P versus 1/V;

   v) n versus 1/T; and vi) n versus 1/P.

   Ans: i) V versus P; and vi) n versus 1/P

3. Calculate the pressure in an evacuated 500 cm^3 container at -33°C when 4.00g of liquid oxygen is introduced into it and allowed to evaporate.

   The Ideal Gas constant is 8.31$JK^{-1}mol^{-1}$. O = 16.0

   Ans: The Ideal Gas equation may be used. P = nRT/V.

   Mol of O_2 = 4.00/32.0; T = 240K; V = 0.500dm^3.

   Pressure in the container P = [(1/8)*8.31*240]/0.500 = 499kPa.

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1. Why did Rutherford and his team choose gold for the foil in the α–particle scattering experiment?

   Ans: 1) Gold is the most malleable metal and can be beaten into very thin sheets/ foils.

   2) Atoms of gold have heavy nuclei and the chances of the α–particles encountering them are high.

2. Which observation led the team to be able to describe the nature of the nucleus of the gold atom.

   Ans: That some of the α–particles were deflected back (or bounced back)

3. What other observation or observations led the team to conclude that the mass that α–particles collided with and bounced back constituted the nucleus

Ans: A few of the α–particles were deflected through small angles, suggesting that they travelled close to a positively charged unit

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Preamble to all schools:

When $SOCl_2$ reacts with water, gaseous HCl and trioxosulphate(IV) are produced and the balanced equation for the reaction is as follows:

$SOCl_2$ + $2H_2O$ → H_2SO_3 + 2HCl.

Cl = 35.5; S = 32.0; O = 16.0. Molar volume of gas at STP is 22.4dm^3.

1. Calculate the volume of HCl at STP that can be obtained from 35.7g of $SOCl_2$.

   Ans: $SOCl_2$ + $2H_2O$ → H_2SO_3 + 2HCl.
   119 2*22.4dm^3.

   Volume of HCl at STP from 35. 7g $SOCl_2$ = (35.7/119)*44.8 = 13.4dm^3.

2. Calculate the mass of $SOCl_2$ that needs to be hydrolysed to obtain 8.96dm^3 of HCl gas at STP.

   Ans: $SOCl_2$ + $2H_2O$ → H_2SO_3 + 2HCl.
   119 2*22.4dm^3

Mass of $SOCl_2$ needed. = (8.96/44.8)*119 = 23.8g

3. Calculate the mass of $SOCl_2$ that needs to be hydrolysed so that the HCl produced dissolves completely in 250cm^3 of water to give a 2.00moldm^{-3} solution.

Ans: $SOCl_2 + 2H_2O \rightarrow H_2SO_3 + 2HCl$.

Mol of HCl required = (250/1000)*2.00 = 0.500

Mol of $SOCl_2$ that has to react = 0.250

Mass of $SOCl_2$ needed = 0.250*119 = 29.8g

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1. Why is it necessary to have iron and steel articles sometimes plated with chromium?

Ans: i) Chromium is not easily affected by the atmosphere unlike iron which easily rusts;

ii) It gives those articles lustrous or shiny appearance.

2. A sealed vessel at a pressure of 450 kPa contains 4.00 moles of nitrogen, 5.00 moles of oxygen and 6.00 moles of argon. Determine the partial pressure of the nitrogen gas.

Ans: Mole fraction of N_2 = 4.00/15.0

Partial pressure of N_2 = (4.00/15.0)*450 = 120kPa

3. If chlorine has the atomic number 17 then what is the atomic number of chromium?

Ans: 24 [17 + 1 → inert gas; + 2 →Groups I and II; + 4 → 4th transition member]

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1. For the analyses of a mixture of Na_2CO_3 and $NaHCO_3$ in a solution, which indicator will enable the concentration of the Na_2CO_3 be determined in only one set of titrations.

Ans: Phenolphthalein.

2. Which of the pH indicators, phenolphthalein, or methyl orange, will be appropriate for the titration of dilute ethanoic acid solution vs dilute sodium hydroxide?

Ans: Phenolphthalein

3. Which of the pH indicators, phenolphthalein, or methyl orange, will be suitable for hydrochloric acid – sodium hydroxide titration?

Ans: Either of the two will be suitable.(If only one choice, one mark)

---

1. Two half-cells, A^+/A and B^+/B have the electrode potentials 0.600V and -0.550V, respectively. Give the cell reaction of a cell that can generate electricity and its initial emf.

Ans: Anode: $B - e \rightarrow B^+$ +0.550V

Cathode: A^+ + e → A 0.600V

Cell reaction: B + A^+ → B^+ + A Emf = 1.15V

2. Two half-cells, C^+/C and D^+/D have electrode potentials -0.430V and -0.850V, respectively. Give the equation for reaction of the cell that can be created from the half-cells and calculate its initial emf.

Ans: Anode: D - e → D^+ +0.850V

Cathode: C^+ + e → A -0.430 V

Cell reaction: D + C^+ → D^+ + C Emf = +0.420V

3. Two half-cells, E^{2+}/E and F^+/F have electrode potentials +0.700V and +0.260V, respectively. Calculate the initial emf of a cell that can be created from the half-cells and give the equation for the cell reaction.

Ans: Anode: F - e → F^+ -0.260V ….(1)

Cathode: E^{2+} + 2e → E +0.700 V ….(2)

Multiply (1) by 2 and add to (2)

Cell reaction: 2F + E^{2+} → $2F^+$ + E Emf = +0.440V

---

1. A gas cylinder at 28°C contains 4.00 mol of oxygen gas, 3.50 mol of carbon(IV) oxide, and 3.50mol of nitrogen gas. If the total pressure is 330kPa, how many mol of argon gas can be added to raise the pressure to 380kPa at the same temperature.

Ans: Total mol of gases originally present = 11.0

Since the gases do not react, pressure exerted by each mole of gas = 330/11.0

= 30.0kPa

Mol of argon needed = (380 -330)/30.0 = 1.67mol

2. State the main factor that is responsible for the variation of the first ionisation energy down a Group of the Periodic Table.

Ans: Increase in the atomic size down the Group.

3. State the postulate of the Kinetic Theory of Gases that best explains the fact that the pressure exerted by a gas is uniform throughout its container.

Ans: Molecules move randomly in straight lines in all directions and at various speeds.

---

1. Give the first step of the reaction mechanism for the chlorination of butane in the presence of light.

Ans: Dissociation of a chlorine molecule into free radicals or chlorine atoms, each with an unpaired electron.

2. Explain what happens in a chain terminating step.

   Ans: Two free radicals, at least one of them involved in chain propagating step, come together to form a neutral compound that is not a free radical.

3. How many dichlorobutanes, can be formed in the free radical reaction of butane and chlorine gases, such that the two chlorine atoms are not located on the same carbon. Name any two of them.

   Ans: Four.

   Any two of: 1,2-dichlorobutane; 1,3-dichlorobutane; 1,4-dichlorobutane; 2,3-dichlorobutane

---

1. Two sparingly soluble metal hydroxides MOH and $Q(OH)_2$, have solubility products of $9.00*10^{-14}$ and $1.08*10^{-19}$, respectively. Find the solubility of each hydroxide and indicate which is more soluble.

   Ans: Solubility of MOH = $\sqrt{9.00 * 10^{-14}}$ = $3.00*10^{-7}$ moldm^{-3}.

   Solubility of $Q(OH)_2$ = $\sqrt[3]{\frac{108}{4} * 10^{-21}}$ = $3.00*10^{-7}$ moldm^{-3}

   Hence, they are of equal solubility.

2. Some radioactive nuclei decay by beta emission. What is the process equivalent to and how does it affect atomic and mass numbers?

   Ans: It is equivalent to the conversion of a neutron to a proton in the nucleus. Hence the atomic number of the new nuclide increases by one while the mass number remains the same.

3. What is the discipline ‘Thermodynamics’ about?

Ans: It is the science or study of the relationship between heat energy and the other forms of energy.

Preamble to all schools

Consider the following results of a kinetic experiment involving the reaction:

$$2A + 2B \rightarrow 3C$$

Experiment	Conc. of A /moldm^{-3}	Conc. of B/moldm^{-3}	Rate(moldm^{-3}s^{-1})
1	0.0300	0.0300	7.20*10^{-4}
2	0.0600	0.0300	2.88*10^{-3}
3	0.0600	0.0600	5.76*10^{-3}

1. Determine the order of the reaction with respect to A.

   Ans: Consider, Experiments (1) and (2).

   Doubling the concentration of A, while keeping the concentration of B constant, the rate increases by a factor of 4.

   Hence the reaction is second order with respect to A.

2. Determine the order of the reaction with respect to B.

   Ans: Consider Experiments (2) and (3).

   Keeping the concentration of A constant while doubling the concentration of B increases the rate by a factor of 2.

   Hence the order of the reaction with respect to B is first order.

3. The reaction is second order with respect to A and first order with respect to B. Use this information and the results of Experiment 1 to calculate the rate constant of the reaction.

   Ans: Rate = k $[A]^2[B]$

   $7.20*10^{-4} = k\,[3.00*10^{-2}]^2[3.00*10^{-2}]$

   $7.20*10^{-4} = k\,[2.70*10^{-5}]$

   $k = 7.20*10^{-4}/2.70.*10^{-5} = 2.67*10^1$ mol^{-2}dm^{6}s^{-1}

   (Full marks may be awarded even if no units are given.)

---

1. How many d-electrons does an element with atomic number 25 possess?

   Ans: 5 d-electrons [25 ≡ $1s^22s^22p^63s^23p^64s^23d^5$]

2. How many p-orbitals will be occupied with paired electrons in an element with atomic number 15?

   Ans: 3 p-orbitals [15 = $1s^22s^22p^63s^23p^3$]

3. Which Period in the Periodic Table will the element with atomic number 34 belong?

Ans: Period 4 [32 = Period1 ($1s^2$) Period2 ($2s^22p^6$) Period 3 ($3s^23p^6$) Period4 ($4s^23d^{10}4p^4$)

---

1. What type of reaction takes place between alkenes and bromine molecules? Give the general type of product formed?

   Ans: Type of reaction: Addition reactions. Product: (1,2-)Dibromoalkane

2. Name the type of reaction and the product formed when sodium hydroxide solution reacts with a primary alkyl halide.

   Ans: Type of reaction: It is substitution reaction. Product: An alkanol

3. Give the reaction mechanism or the chemical steps followed when hydrogen bromide gas reacts with an alkene.

   Ans: In **Step 1** the pi-cloud of the alkene attacks/attracts the proton of the HBr to form a carbocation. In **Step 2** the bromide ion reacts with the carbocation to give a bromoalkane. [In both steps it is the electron pair that attacks]

Preamble to all schools:

Ammonium dichromate $(NH_4)_2Cr_2O_7$ decomposes on heating according to the following balanced equation:

$$(NH_4)_2Cr_2O_7 \rightarrow N_2\uparrow + 4H_2O + Cr_2O_3$$

Cr = 52.0; O = 16.0; N = 14.0; H = 1.00

1. Calculate the percentage loss in mass when the salt decomposes to give Cr_2O_3.

   Ans: $(NH_4)_2Cr_2O_7 \rightarrow N_2 + 4H_2O + Cr_2O_3$

   252 152

   Loss in mass = 252 - 152 = 100

   %Loss in mass = (100/252)*100 = 39.7

2. Calculate the mass of the oxide that can be obtained from 378g of the ammonium compound if the yield is 90.0%.

   Ans: $(NH_4)_2Cr_2O_7 \rightarrow N_2 + 4H_2O + Cr_2O_3$.

   252 152

   Mass of the oxide from 378g of the salt = (378/252)*152 = 228g

Actual yield = 0.900*228 = 205g

3. Calculate the volume of nitrogen gas at STP that can be generated from 2.016kg of the ammonium compound. The molar volume of an ideal gas at STP is $22.4dm^3$.

Ans: $(NH_4)_2Cr_2O_7 \rightarrow N_2 + 4H_2O + Cr_2O_3$.

252 $22.4dm^3$

Volume of nitrogen at STP = (2016/252)*22.4 = $1.79*10^2dm^3$.

---

1. Give the units of the rate constant of a second order reaction for which the concentrations of reactants are given in ppm or parts per million.

Ans: The general units are $conc^{-1}\ s^{-1}$ hence $(ppm)^{-1}s^{-1}$ or million per part second.

2. If it is the intention to prepare metallic sodium by electrolysis, which electrolyte is better and why: concentrated sodium chloride solution or fused sodium chloride?

Ans: Fused sodium chloride is preferred. Reason: In an aqueous solution Na^+ and H^+ are available to be reduced at the cathode; H^+ has the higher electrode/reduction potential hence H_2 will be formed instead of metallic sodium.

3. $20.0dm^3$ of nitrogen gas kept at a temperature of 87.0^oC and a pressure of 95.0kPa is allowed to cool to -3.00^oC at a pressure of 100kPa. Calculate the new volume of the gas.

Ans: Use the Ideal Gas Equation: $P_1V_1/T_1 = P_2V_2/T_2$; $V_2 = V_1(P_1/P_2)(T_2/T_1)$

P_1 = 95.0kPa; V_1 = $20.0dm^3$; T_1 = 360K; P_2 = 100kPa; T_2 = 270; V_2 = ?

V_2 = (20.0*95.0*270)/(360*100) = 14.25 = $14.3dm^3$

---

1. How do the atomic number and mass number change when a radioactive element decays by electron emission?

Ans: Atomic number increases by 1, mass number remains unchanged.

2. How do the atomic number and mass number change when a radioactive element decays by electron capture?

Ans: Atomic number decreases by 1, mass number remains unchanged.

3. How do the atomic number and the mass number change when a radioactive nuclide emits a neutron and gamma ray at the same time?

   Ans: Atomic number remains unchanged and mass number decreases by 1.

---

1. What mass of magnesium tetraoxosulphate(VI) heptahydrate is needed to prepare a 400 cm^3 solution of 0.150 $moldm^{-3}$ concentration?

   Mg = 24.0; S = 32.0; O = 16.0; H = 1.00

   Ans: $MgSO_4 \cdot 7H_2O$ = 56.0 + 64.0 + 7*18.0 = 120 + 126 = 246

   Mass required to prepare 1 dm^3 solution of 0.150$moldm^{-3}$ = 246*0.150 = 36.9g

   Therefore, mass needed for 400 cm^3 solution of 0.150$moldm^{-3}$ = 36.9*0.400 = 14.8g

2. Calculate the mass of $CuSO_4 \cdot 5H_2O$ needed to prepare a 250 cm^3 solution which is 0.450 $moldm^{-3}$ with respect to Cu^{2+} ions.

   Cu = 64.0; S = 32.0; O = 16.0; H = 1.00

   Ans: $CuSO_4 \cdot 5H_2O$ = 96.0 + 64.0 + 5*18.0 = 250

   Mass of the compound needed to prepare 1dm^3 of 0.450 $moldm^{-3}$ Cu^{2+} = 0.450*250

   = 112.5g

   Therefore, mass needed for 250 cm^3 = 112.5/4 = 28.1g

3. Calculate the mass of sodium trioxocarbonate(IV) decahydrate needed to prepare 500cm^3 solution which is 0.240$moldm^{-3}$ with respect to Na^+ ions.

   Na = 23.0; O = 16.0; C = 12.0; H = 1.00

   Ans $Na_2CO_3 \cdot 10H_2O$ = 46.0 + 60.0 + 180 = 286.

   1.00 mol $Na_2CO_3 \cdot 10H_2O$ = 2mol Na^+ ions.

   Mass of the compound needed for 1dm^3 of 0.120$moldm^{-3}$ solution = 286*0.120 = 34.32g

   Mass for 500cm^3 of 0.240$moldm^{-3}$ solution of Na^+ ions = 34.32/2 = 17.2g

---

1. For a substance to be regarded as a suitable catalyst for a reaction, that substance must satisfy some criteria. Give two of such criteria.

   Ans: Any two of the following:

   (i) The catalyst must increase the rate of the reaction.

   (ii) The catalyst is not consumed by the reaction.

(iii) A small quantity of the catalyst should be able to affect the rate of the reaction

(iv) Catalyst does not change the equilibrium constant for the reaction

2. An element X exists as tetra-atomic molecules X_4. If X has two natural isotopes, how many peaks will be observed in its Mass Spectrum? The spectrum is recorded such that there is no fragmentation.

   Ans: 5 peaks.

   Assume isotopes X_1, X_2

   Molecules that are possible are:

   X_1-X_1-X_1-X_1; X_1-X_1-X_1-X_2; X_1-X_1-X_2-X_2; X_1-X_2-X_2-X_2; X_2-X_2-X_2-X_2

3. What is the study of metallurgy about?

   Ans: It is the scientific study of the production of metals from their ores (and the making of alloys.)

Preamble to all schools:

Use the Kinetic Theory of Gases to explain the following experimental observations:

1. For a given gas at constant temperature and volume, the pressure increases when the molar quantity of the gas increases.

   Ans: The Theory predicts that the pressure of a gas results from collision between the gas particles and the walls of the container. When the number of the particles increases, the number of collisions per unit area increases even at constant temperature.

2. For a given amount of gas at a constant volume, the pressure of the gas increases with temperature.

   Ans: A postulate of the Theory states that the average kinetic energy of a gas particle depends only on the temperature of the gas; hence the average kinetic energy increases as the gas gets warmer. The higher average kinetic energy means gaseous particles move faster and collide with the wall of its container with greater force, and more frequently, hence increase in pressure.

3. For a given quantity of a gas, at constant temperature the pressure is inversely proportional to the volume.

   Ans: As the volume decreases at constant temperature, distances the gaseous molecules have to travel before colliding with the walls of the container decrease hence frequency of collisions increases leading to an increase in pressure.

---

1. If phosphorus is the fifth member of the third Period of the Periodic Table what is its atomic number?

   Ans: 15 [2 + 8 + 5]

2. If calcium, the third member of Group II of the Periodic Table has the atomic number 20 what is the atomic number of barium, the fifth member of the same Group?

   Ans: 56 [20 + 18 + 18]

3. If krypton, the last member of Period 4 has the atomic number 36 what is the atomic number of zinc, a member of the same Period?

   Ans: 30 [36 – 6; Ga, Ge, As, Se, Br, Kr]

Preamble to all schools.

Gaseous butanone will burn in oxygen to give carbon(IV) oxide and water vapour.

Consider the following bond energies all in $kJmol^{-1}$.

C – C 347; C – H 413; C – O 358; C = O 805; O – H 464; O_2 494

4. Give a balanced equation for the combustion of one mole of 2-butanone and give the type and respective number of bonds to be broken.

   Ans: $CH_3COCH_2CH_{3(g)}$ + $11/2O_{2(g)}$ → $4CO_{2(g)}$ + $4H_2O_{(g)}$.

   Bonds to be broken = 3C – C + 8C -H + 1C = O + $5.5O_2$.

5. Calculate the enthalpy change for the formation of the necessary bonds in the combustion of gaseous 2-butanone.

   Ans: Bonds to be formed = 8C = O + 8O -H

   Enthalpy change = -8*805 + (-8*464) = -10,152kJ or -10,200 or $-1.02*10^4$kJ

6. Calculate the energy required to break all the necessary bonds in the combustion of 2–butanone.

   Ans: Bonds to be broken = 3C – C + 8C -H + 1C = O + $5.50O_2$.

   Energy required = 3*347 + 8*413 + 805 + 5.50*494 = +7867kJ or +7,870 or $+7.87*10^3$ Kj

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1. A 2.00dm^3 flask is filled with argon gas at 27.0 °C until the pressure is 70.0 kPa. Calculate the total pressure when 6.40 g of O_2 gas at 27.0^{o}C is added to the flask. Ideal Gas constant R is 8.31 $JK^{-1}mol^{-1}$. O = 16.0

   Ans: Moles of O_2 in 6.40g = 6.40/32.0 = 0.200

   Pressure of 0.200 mol of O_2; P_{O2} = (nRT)/V

   P_{O2} = (0.200 *8.31 *300)/2.0 = 8.31*30.0 = 249.3 kPa

   Total pressure = (70.0 + 249.3) kPa = 319 kPa

2. State the hybridization of the carbon orbitals in the ion HCO_3^-.

   Ans: sp^2.

3. Which of the following elements has the lowest first ionisation energy: chlorine, phosphorus, and sulphur?

   Ans: Sulphur (P 1012; S 1000; Cl 1251kJmol-1)

Preamble to all schools

Values of the first ionisation energies for the first 20 elements (hydrogen to calcium) show several clear patterns. State any one of them and give reasons for that pattern.

Ans: (i) The first ionisation energy (IE) generally increases appreciably as we go across a Period.

Reason: Across a Period, the effective nuclear charge increases, and the atomic radius decreases. Hence it becomes more difficulty to remove an electron from the valence shell.

(ii) There is a gradual decrease of the first ionisation energy as we go down a Group.

Reason: Down a Group, atomic radius increases hence the attractive force of the nucleus on the outermost electrons decreases. It becomes easier to remove an electron from the valence shell.

(iii) There are minor exceptions in a Period. e.g. Be, B or N, O or Mg, Al

Reason: Relative Stability of the electron configuration becomes significant in some instances. Removing an electron to give a half- or fully-filled sub-shell like B or O respectively is more favourable despite higher effective nuclear charge and smaller atomic radius than removing an electron from half- or fully-filled sub-shell like N or Be.

(iv) There is a big drop in the first ionisation (IE) as we go from the end of one period to the beginning of the next period

Reason: The end of a Period is occupied by an inert gas. Its atoms have fully filled shells and hence possess very stable electronic configuration and high ionisation potential. The element next after an inert gas is an element that begins a new Period and will have a valence shell of ns^1. Losing that electron will be thermodynamically very favourable.

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1. Give the systematic names of the compounds that will be obtained by acid hydrolysis of N-methylpropanamide.

   Ans: (1) Propanoic acid and (2) Methylamine or methanamine

2. Name the ester that will be formed when pentanoic acid is made to react with 1-butanol.

   Ans: Butyl pentanoate

3. Name the major product formed when 1-pentene undergoes an addition reaction under appropriate conditions with a molecule of water.

   Ans: 2-Pentanol

---

1. Calculate the pH of 0.100 $moldm^{3}$ solution of chloroethanoic acid whose pK_a is 2.86.

   Ans: $pH = \frac{1}{2} pK_a - \frac{1}{2} \log C_a$

   $= 2.86/2 + 0.500 = 1.43 + 0.500 = 1.93$

2. Calculate the pH of 0.100 $moldm^{3}$ solution of ethanolamine, whose pK_b is 4.50.

   Ans: $pOH = \frac{1}{2} pK_b - \frac{1}{2} \log C_b$

   $= 4.50/2 + 0.5 = 2.25 + 0.500 = 2.75$

   $pH = 14.0 - pOH = 14.0 - 2.75 = 11.3.$

3. Oxoiodate(I) acid, HOI is weak inorganic acid. If its 0.100 $moldm^{-3}$ solution has a pH of 5.82 find the pK_a of the acid.

   Ans: $pH = \frac{1}{2} pK_a - \frac{1}{2} \log C_a$

   Hence $5.82 = \frac{1}{2} pK_a + 0.500$

   $pKa = 2*5.32 = 10.6$

---

1. Name the elements in Period 3 that form pure ionic hydrides.

   Ans: Sodium and magnesium.

2. Give the hybridisation of the bonding orbitals of beryllium in its hydride.

   Ans: sp

3. Calcium ethanedioate has a solubility product of $4.00 *10^{-10}$ at about 30 ^0C. Calculate the solubility of this salt in water and in 0.100 $moldm^{-3}$ Ca^{2+} solution. Account for the difference if any.

Ans: In water Ksp of $CaC_2O_4 = 4.00*10^{-10}$; Solubility = $\sqrt{(4.00*10^{-10})}$

Hence $[Ca^{2+}]$ or $[C_2O_4^{2-}]$ = $2.00 *10^{-5}$ moldm^{-3}

In 0.100 moldm^{-3} Ca^{2+}:

Ksp = $[0.100][C_2O_4^{2-}]$ = $4.00*10^{-10}$

$[C_2O_4^{2-}]$= $4.00 *10^{-9}$ moldm^{-3}

Solubility in Ca^{2+} solution is lower, due to common ion effect.

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1. Extraction of gold involves two general processes. What are these?

   Ans: i) Concentration and ii) Purification.

2. To concentrate gold from its ore, the ore in some cases is roasted in kilns. Explain how this leads to the concentration of gold.

   Ans: For ores obtained from deep mines (in Obuasi, Ghana) the ores contain arsenic sulphides and roasting expels the arsenic and sulphur as gaseous oxides.

3. Explain which process in the extraction of aluminium from bauxite may be regarded as concentration of the metal.

   Ans: The raw bauxite is treated with concentrated NaOH solution to remove sand and other impurities.

---

1. Give the products of decomposition when ammonium trioxonitrate(V) is heated.

   Ans: Nitrogen (I) oxide and water/steam

   $[NH_4NO_3 \rightarrow N_2O + 2H_2O]$

2. Give the products of decomposition when potassium trioxonitrate(V) is heated.

   Ans: Potassium dioxonitrate(III) and oxygen gas

   $[2KNO_3 \rightarrow 2KNO_2 + O_2]$

3. Give the products of decomposition when barium trioxonitrate(V) is heated.

   Ans: Barium oxide, nitrogen(IV) oxide, and oxygen gas.

   $[2Ba(NO_3)_2 \rightarrow 2BaO + 4NO_2 + O_2]$

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1. Radium–226, atomic number 88 undergoes alpha emission to give a new nuclide. Give a balanced equation for this decay.

   Ans: ${}^{226}_{88}Ra \rightarrow {}^{222}_{86}X + {}^{4}_{2}\alpha$

2. Radium–226, atomic number 88, can undergo an alternative decay instead of alpha emission, yielding the same daughter nuclide but different emissions. State the emissions and give a balanced equation for this decay.

   Ans: Other decay: emission of two protons and two neutrons

   $${}^{226}_{88}Ra \rightarrow {}^{222}_{86}X + 2{}^{1}_{1}p + 2{}^{1}_{0}n$$

3. Plutonium–239, atomic number 94 undergoes a radioactive decay accompanied by a type of emission that can be used as source of power for a heart pacemaker. If the new nuclide is uranium–235, atomic number 92, give a balanced equation for the decay and state the type of emission which can serve as the source of energy.

   Ans : $${}^{239}_{94}Pu \rightarrow {}^{235}_{92}U + {}^{4}_{2}\alpha$$

   Hence source of energy = α – emission.

---

1. Chlorofluoromethanes were used as refrigerants and spray-can propellants, but they have been banned. Why?

   Ans: Chlorofluoromethanes decompose to give chlorine atoms which serve as catalyst for the decomposition of ozone in the stratosphere.

2. Hydrogen peroxide concentration of 6.00% w/v is a good antiseptic. If you buy a bottle of hydrogen peroxide labelled 10.0% w/v, how would you prepare a 500 cm^3 of 6.00% w/v H_2O_2 from that?

   Ans: Dilution: 10.0% w/v to 6.00% w/v; Dilution factor 3 in 5

   Measure 300 cm^3 of the 10.0% w/v and make it up to 500 cm^3 with clean water.

3. In a solution of butanal in tetrachloromethane what will be the attractive forces between butanal and tetrachloromethane molecules?

   Ans: Dipole – Induced dipole forces

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1. The Group I elements are soft, metallic solids with low melting point. What accounts for this physical nature?

   Ans: They are made up of large atoms which result in weak metal bonds.

2. The Group I elements are the most reactive metallic elements. What could be the reason for this.

   Ans: They have low first ionisation energies thus losing the ns^1 electron readily to form +1 cations.

3. Use the reactions with water to illustrate reactivity of Group I metals down the Group.

   Ans: Reactivity increases down the Group. They all react with water. Lithium reacts with water gently but readily. Sodium and Potassium react vigorously. Reactions with Rubidium and Caesium are explosive/violent.

Preamble to all schools:

Each school will be presented with two named organic compounds. i) Give the molecular formula of each and hence state if they are isomers. ii) If they are isomers determine the type of isomers that they are.

1. Cyclopentane and 2-pentene.

   Ans: They both have the same formula, C_5H_{10}, hence they are isomers. They are structural isomers.

2. Cyclohexene and 1-hexyne

   Ans: They both have the formula C_6H_{10} hence they are isomers. They are functional Group isomers.

3. *d*-2-Butanol and *l*-2-butanol

   Ans: They both have the formula $C_4H_{10}O$, hence they are isomers. They are stereoisomers or enantiomers.

Preamble to all schools:

The IO_3^- ion reacts with the iodide ion in acidic medium according to the following equation:

$$IO_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_2O \quad (1)$$

The iodine liberated can be titrated against $Na_2S_2O_3$ solution using starch as indicator. The equation for that reaction is as follows:

$$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-} \quad (2)$$

1. To 20.0 cm^3 of KIO_3 solution excess KI solution and dilute H_2SO_4 are added, and the liberated iodine titrated against 0.400 $moldm^{-3}$ solution of $Na_2S_2O_3$. If the titre is 24.0 cm^3, calculate the concentration in $moldm^{-3}$ of the KIO_3 solution.

   Ans: From equations (1) and (2); $n(IO_3^-)/n(S_2O_3^{2-})$ = 1/6

   (20.0 *M)/(0.400 *24.0) = 1/6; M = (0.400*24.0)/(6*20.0)

   Concentration of KIO_3 solution, M = 0.0800$moldm^{-3}$

2. 0.00064 mol of KIO_3 is dissolved in enough water, excess dilute H_2SO_4 and KI solution are added, and the iodine liberated is titrated against 0.200 $moldm^{-3}$ solution of $Na_2S_2O_3$. Calculate the expected titre.

   Ans: Let Vcm^3 be the titre; $n(KIO_3)/n(Na_2S_2O_3)$ = 1/6

   Millimoles of $Na_2S_2O_3$ = (0.200*V); Millimoles of KIO_3 = 0.640

   0.640/(0.200*V) = 1/6; V = (6 *0.640)/0.200

   Titre V = 19.2 cm^3

3. Calculate the volume of 0.500 $moldm^{-3}$ H_2SO_4 that has to be added to a titration in which 0.000450 mol of KIO_3 is used. Note that in practice the amount of acid has to be ten times in excess.

   Ans: Let the exact volume of H^+ be Vcm^3.

   From the H_2SO_4, the H^+ concentration = 1.00 $moldm^{-3}$

   mmol(IO_3^-)/mmol H^+ = 1/6; (0.450)/(V *1.00) = 1/6

   Volume V of H^+ = (6 *0.450)/1 = 2.70 cm^3

   The exact volume of H_2SO_4, = 1.35 cm^3; Ten times in excess = 13.5 cm^3

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1. State Avogadro's Law

   Ans: Equal volumes of any two gases at the <u>same temperature and pressure</u> contain the same number of molecules.

2. NO_2 dimerises in a reversible process to give N_2O_4 according to the following equation:

   $$2NO_2 \rightleftharpoons N_2O_4$$

   In one such reaction, a 1.00dm^3 flask was charged with 2 mole of NO_2 and heated to 150 ^oC. At equilibrium, it was found that 0.400 mol of N_2O_4 was formed. Find the equilibrium constant.

   Ans: $2NO_2 \rightarrow N_2O_4$

   Initial: 2.00 mol 0

Equil: 2 – 0.800 0.400

$K_C = (0.400/(1.20)^2) = 0.400/1.44 = 0.278$ or $2.78*10^{-1}$.

3. Give the oxidation state of chromium in the chromium complex cation $[Cr(NH_3)_5NO_2]^{2+}$.

   Ans: +3

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1. Give the relative positions of the slag and the molten metallic iron in the Blast Furnace during the extraction of iron and explain why those relative positions.

   Ans: The slag floats on top of the iron at the bottom of the furnace.

   Explanation: The slag is less dense than the molten iron.

2. Biotechnology may be used to extract gold from its ore. Explain how this is done?

   Ans: Some microbes are introduced into a suspension of the powdered ore in water.

   The microbes feed on the impurities and free the gold.

3. Bauxite usually has sand and iron(III) oxide as impurity. Explain how aluminium oxide is separated from these impurities.

   Ans: The ore is treated with concentrated solution of NaOH. Aluminium oxide and silica (or silicon dioxide) dissolve in the concentrated solution of NaOH while iron(III) oxide remains undissolved. Aluminium hydroxide $Al(OH)_3$ prcecipitates when the solution is seeded.

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1. Name the reagent that can be used to convert ethylbenzene into benzoic acid.

   Ans: Hot, acidified $KMnO_4$ solution.

2. What reagents are needed for the iodoform test?

   Ans: KOH solution and iodine

3. Name the product formed when 1-butene is treated with dilute, neutral $KMnO_4$ solution.

   Ans: 1,2-butandiol or butan-1,2-diol

Preamble to all schools:

Ammonia gas burns in pure oxygen gas to nitrogen gas and steam. The balanced equation for the reaction is as follows: $4NH_{3(g)} + 3O_{2(g)} \rightarrow 2N_{2(g)} + 6H_2O_{(g)}$.

Also consider the following bond energies all in $kJmol^{-1}$; N – H 386; O – H 459; N ≡ N 942; N = O 607 O_2 494.

1. Calculate the energy required to break all the necessary bonds in the combustion of ammonia gas in pure oxygen

Ans: $4NH_{3(g)}$ + $3O_{2(g)}$ → $2N_{2(g)}$ + $6H_2O_{(g)}$.

Bonds broken = 12 N – H + $3O_2$

Energy required= 12*386 + 3*494 = 6,114kJ or $6.11*10^3$kJ

2. If the energy required to break all the bonds in the combustion is 6,114kJ, calculate the enthalpy change for the reaction.

Ans: $4NH_{3(g)}$ + $3O_{2(g)}$ → $2N_{2(g)}$ + $6H_2O_{(g)}$.

Bonds to be formed = 2N ≡ N + 12O – H.

Energy given out = -2*942 + -12*459 = -7,392kJ

Enthalpy of reaction = -7,392 + 6,114kJ = -1,278kJ or -$1.28*10^3$kJ

3. In the presence of a platinum catalyst ammonia burns in oxygen to give nitrogen(II) oxide and steam and the balanced equation is as follows: $4NH_{3(g)}$ + $5O_{2(g)}$ → $4NO_{(g)}$ + $6H_2O_{(g)}$. If the energy required to break all the necessary bonds is 7,102kJ and assuming that the NO molecule contains nitrogen – oxygen double bond, calculate the enthalpy of reaction.

Ans: $4NH_{3(g)}$ + $5O_{2(g)}$ → $4NO_{(g)}$ + $6H_2O_{(g)}$

Bonds to be formed = 4N = O + 12O – H.

Energy given out = -4*607 + -12*459 = -7,936kJ

Enthalpy of reaction = 7,102 – 7,936 = -834kJ

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1. A metal alloy made from aluminium (Al), magnesium (Mg), copper (Cu) and steel has the composition:

Al 18.0%; Mg 12.0%; Cu 25.0%. The rest is steel, which is 98.5% iron and 1.50% carbon. Calculate the mass in gram of carbon in a 2.00 kg alloy.

Ans: % steel = 100 – (18.0 + 12.0 + 25.0) = 45.0

Therefore, in 2.00 kg alloy, mass of steel= 450*2 = 900g

Mass of carbon = (1.5/100)*900 = 13.5 g

2. Both CaO and anhydrous $CaCl_2$ can be used to dry wet gases. Which solid would be suitable for CO_2 gas?

   Ans: $CaCl_2$

3. Whereas the water molecules in the salt $ZnSO_4 \bullet 7H_2O$ are not taken into consideration when determining the oxidation number of zinc, the water molecules in the complex ion $[V(H_2O)_6]^{3+}$ have to be considered when determining the oxidation state of vanadium. Why?

   Ans: The water molecules in the salt are not directly bonded to zinc whereas those in the vanadium complex ion are bonded to vanadium.

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1. State the Aufbau Principle (or Building–up Principle).

   Ans: Electrons always occupy the lowest empty energy level.

2. State Pauli's Exclusion Principle.

   Ans: No two electrons in an atom can have exactly the same energy.

3. State Hund's Rule

   Ans: When electrons fill a subshell, every orbital in the subshell is occupied by a single electron before any orbital is doubly occupied (and all electrons in singly occupied orbitals have their spins in the same direction).

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1. Extraction of metals go through three stages or processes. Give the three process.

   Ans: (a) Concentration of the ore/metal/metal compound.

   (b) Chemical reduction of the ore/metal compound.

   (c) Purification of the metal.

2. Pick the pairs whose solutions will act as a buffer.

   H_3PO_4, $NaHCO_3$, HCl, NH_3, HPO_4^{2-}, $H_2PO_4^-$, $NaOH$, NH_4Cl ,

   Ans: i) H_3PO_4/ $H_2PO_4^-$ ii) $H_2PO_4^-$ / HPO_4^{2-} iii) NH_3/ NH_4Cl.

3. Explain why SO_2 gas is not the anhydride of H_2SO_4 acid.

   Ans: An anhydride of a substance reacts with water without going through any redox reaction. The sulphur in SO_2 and H_2SO_4 are in different oxidation states so conversion of the gas to the acid will involve a redox reaction.

1. Calculate the concentration of an Na_2CO_3 solution if 20.0 cm^3 of it requires a titre of 24.0 cm^3 of 0.0950 $moldm^{-3}$ of an HCl solution in a titration using methyl orange as indicator.

   Ans: $2HCl + Na_2CO_3 \rightarrow 2NaCl + CO_2 + H_2O$

   24.0, 0.0950   20.0, M

   (24.0*0.0950)/(20.0*M) = 2/1

   Concentration of Na_2CO_3 solution, M = (24.0*0.0950)/(20.0*2) = 0.0570 $moldm^{-3}$.

2. Iron (II) reacts with acidified solution of MnO_4^- in the ratio 5:1. Calculate the concentration of a solution of Fe^{2+} ions if 20.0cm^3 of it required 15.0 cm^3 of 0.120 $moldm^{-3}$ of acidified solution of MnO_4^- for complete reaction.

   Ans: $MnO_4^- + 5\ Fe^{2+} + 8\ H^+ \rightarrow$ products

   15.0, 0.120   20.0, M

   (15.0*0.120)/(20.0*M) = 1/5

   Concentration of Fe^{2+}, M = (5*15.0*0.120)/20.0 = 0.450 $moldm^{-3}$

3. Iodine reacts with the $S_2O_3^{2-}$ ion in a 1:2 ratio. If 20.0 cm^3 of an iodine solution of unknown concentration reacted completely with 18.0 cm^3 of 0.0640 $moldm^{-3}$ of $S_2O_3^{2-}$ solution, then what is the concentration of the iodine solution?

   Ans: $I_2 + 2\ S_2O_3^{2-} \rightarrow$ product

   20.0, M   18.0, 0.0640

   (18.0*0.064)/(20.0*M) = 2/1

   Concentration of iodine, M = (18.0*0.0640)/(2*20.0) = 0.0288 $moldm^{-3}$

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1. Two half – cells, M^+/M and Q^+/Q where M and Q are metals, have the electrode potentials 1.20 and -0.850 volts, respectively. Which of the two metals can react with dilute mineral acid to release hydrogen gas? Give your reason.

   Ans: Q. Reason: The potential for the reaction $Q \rightarrow Q^+ + e$ is positive whereas the potential for the similar reaction of M is negative. The one with the positive oxidation potential can oxidise H^+ to H_2.

2. Give the main difference in the definitions of an acid according to the Arrhenius Theory and according to the Bronsted–Lowry Theory.

Ans: The Arrhenius concept of acid is limited to a substance that increases H^+ concentration in water but Bronsted–Lowry concept makes any proton donor an acid irrespective of the medium.

3. Butane isomerises to 2-methylpropane or isobutane in an equilibrium process. If a $1.00dm^3$ flask is charged with 2.00 mole of butane at 30°C and the gas allowed to come to equilibrium, calculate the equilibrium concentration of butane and isobutane at 30°C given that the equilibrium constant, K_c is 2.50.

Ans: Butane ⇌ isobutane K_c = 2.50

Initial:	$2.00\ moldm^{-3}$			$0.00\ moldm^{-3}$		
At eq.:	$2.00 - x\ moldm^{-3}$			$x\ moldm^{-3}$		
K_c =	$x/(2.00 - x)$	=	2.50;	x	=	$5.00 - 2.50x$
3.50x =	5.00;			x	=	1.43.

Hence concentration of butane, 2.00 - x = $0.570moldm^{-3}$;

Concentration of isobutane, x = $1.43moldm^{-3}$.

Preamble to all schools.

Each school will be presented with an incomplete statement. You are to complete the statement.

1. In the Periodic Table, sodium is to phosphorus as potassium is to

   Ans: Arsenic

2. In the Periodic Table, titanium is to chromium as iron is to

   Ans: Nickel

3. In the Periodic Table, lithium is to magnesium as boron is to

   Ans: Silicon.

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1. What is the percentage by mass of oxygen in the earth's crust?

   Ans: 47.0% (Accept ±1)

2. What is the percentage by volume of nitrogen in the earth's atmosphere?

   Ans: 78.1% (Accept ± 1)

3. What is the percentage by volume of argon in the earth's atmosphere?

   Ans: 0.93% (Accept ± 0.05)

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1. Calculate the percent magnesium by mass in ethyl magnesium bromide.

   Br = 80.0; Mg = 24.0; C = 12.0; H = 1.00.

   Ans: C_2H_5MgBr = 29.0 + 24.0 + 80.0 = 133

   % Mg = (24.0/133)*100 = 18.0%

2. When magnesium chloride is recrystallised at room temperature a hexahydrate is formed .

   Calculate percent magnesium by mass in this hydrated salt.

   Cl = 35.5; Mg = 24.0; O = 16.0; H = 1.00.

   Ans: $MgCl_2 \cdot 6H_2O$ = 24.0 + 71.0 + 6*18.0 = 203.

   %Mg = (24.0/203)*100 = 11.8

3. Find the percent tetraoxophosphate(V) or simply phosphate by mass in the salt magnesium ammonium tetraoxophosphate(V) hexahydrate. P = 31.0; Mg = 24.0; O = 16.0 N = 14.0; H = 1.00.

   Ans: $MgNH_4PO_4 \cdot 6H_2O$ 24.0 + 18.0 + 31.0 + 64.0 + 6*18.0 = 245

   % PO_4^{3-} = (95.0/245)*100 = 38.8

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1. A chemical reaction produces 4.00 moles of oxygen gas. What volume will the oxygen gas occupy at a room temperature of 27.0 ^{0}C if the pressure is maintained at 100 kPa throughout the experiment? Molar volume of a gas at STP = 22.4 dm^3; Gas constant = 8.31 $JK^{-1}mol^{-1}$

   Ans: <u>Use Charles' law</u>: V α T at constant pressure and number of moles.

   V_1 = 4.00 *22.4; T_1 = 273; V_2 = ?; T_2 = 300

   V_2 = (T_2/T_1) *V_1 = (300/273)*4.00*22.4 = **98.5 dm^3**

   OR <u>Use the Ideal Gas Equation</u>; V = (n *R *T)/ P

   V = (4.00 *8.31 *300)/100= **99.7 dm^3**

   (Accept either of the two answers)

2. How many *pi* bonds are present in the H_2SO_4 molecule?

Ans: Two (2) pi bonds.

3. Explain why even though both phenol and ethanol contain the OH group, phenol is an acidic, but ethanol is not.

   Ans: Phenol is an acid because when it loses a proton the conjugate base , the phenoxide ion, is stabilised by resonance whereas the conjugate base of ethanol, the ethoxide ion, is not stabilised by resonance.

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1. What intermolecular forces are present among PBr_3 molecules and why?

   Ans: Dipole – Dipole forces. PBr_3 molecules possess trigonal pyramidal shapes and will possess a net dipole (moment).

2. What type of intermolecular forces will the molecules of chloroethene possess and why?

   Ans: Dipole-dipole forces. The pi cloud of the $ClCH = CH_2$ molecules will be polarised by the presence of the chlorine atom and so the molecules will possess net dipole (moments).

3. What type of intermolecular forces will present among the molecules of HCl and why that type of forces.

   Ans: Dipole -dipole forces. The covalent bond between H and Cl is highly polarised because of the difference in the electronegativities of the two atoms, (but Cl is not electronegative enough to bring about hydrogen bonding.)

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1. Haemoglobin is a red compound whose large molecule is made up of a protein portion, the globin, and a non-protein portion, the haem. The haem is a complex comprising iron(II) and four unsaturated nitrogen heterocycles linked together. What could be the source of the red colour of haemoglobin?

   Ans: [It cannot be the iron(II)]. The colour must be due to the presence of the four unsaturated nitrogen heterocycles (or the porphyrin ring)

2. Palm oil is made up of esters of palmitic (hexadecanoic) acid and stearic (octadecanoic) acid both of them colourless compounds. Why is palm oil red?

   Ans: It contains carotenes which are originally present in the fruits, and which get extracted along with the oil.

3. Ant hills are common in Ghana and especially on the University of Ghana campus. Almost all of them have the brick-red colour. What could be the source of the brick-red colour.

   Ans: The hills consist of soils rich in iron(III) oxides.

Preamble to all schools.

Each school will be given a chemical equation, which may be a redox or a disproportionation, to balance.

1. P_4 + NaOH + H_2O → NaH_2PO_2 + PH_3.
   Ans: P_4 + 3NaOH + $3H_2O$ → $3NaH_2PO_2$ + PH_3.
2. K_2MnO_4 + H_2O → MnO_2 + $KMnO_4$ + KOH.
   Ans: $3K_2MnO_4$ + $2H_2O$ → MnO_2 + $2KMnO_4$ + 4KOH.
3. $MnSO_4$ + PbO_2 + H_2SO_4 → $HMnO_4$ + $PbSO_4$ + H_2O.
   Ans: $2MnSO_4$ + $5PbO_2$ + $3H_2SO_4$ → $2HMnO_4$ + $5PbSO_4$ + $2H_2O$.

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1. Give the two main sources that contribute to background radiation we all receive or are exposed to in our environment on earth.
   Ans: i) Cosmic rays;
   ii) Natural radioactivity of certain radioisotopes in the soil. e.g. K–40, Radium, Radon.
2. Between the molecules of aspirin and paracetamol, two common analgesics the following functional groups can be identified. Indicate which drug has which functional group(s):
   i) Ester ii) Amide iii) Phenol iv) Carboxylic acid.
   Ans: Aspirin: Ester and Carboxylic acid [*o*-HOOC-C_6H_4-$OCOCH_3$]
   Paracetamol: Amide and Phenol [*p*-HO-C_6H_4-$NHCOCH_3$]
3. A flask contains 0.200 mol of nitrogen gas, 0.100 mol of oxygen gas and 0.300 mol of argon gas at a total pressure of 240kPa. How many moles of oxygen gas must be added to the flask to raise the total pressure to 300kPa?
   Ans: Since the gases do not react the Dalton's Law of Partial Pressures apply.
   Moles of gas giving the pressure of 240kPa = 0.600; Additional kPa needed = 60
   Moles of oxygen required to add 60.0kPa = (60.0/240)*0.600
   = 0.150mol.
