National Science Olympiad

Past Examination Questions and Answers (2005-2006): Chemistry Section

BACKGROUND

The South African Agency for Science and Technology Advancement (SAASTA) is the lead agency, mandated by Government to promote and advance science and technology on a national level. SAASTA has been incorporated into the National Research Foundation (NRF) and serves as the science promotion pillar of the organisation. As a science council, the NRF is a non-profit entity, and is committed to supporting the development of human resource capacity for research, technology and innovation in the fields of science and technology.

SAASTA's lead competency lies in the management of large-scale, national programmes in science promotion. Central to our operations are programmes that support school science (learner and educator support programmes, science-based materials resources, etc) and ones that urge young people to pursue science, engineering and technology-based careers. The National Science Olympiad is one of such programme.
SAASTA is committed to high quality delivery of science and technology promotion programmes that will build the pool of competent learners in mathematics and science, and enhance the scientific skills base of the country, thus increase the SET human capital.

The National Science Olympiad

The National Science Olympiad is a project which was originally established for grade 12 learners with the objective of promoting Physical Science. Now in its 43rd year, the competition continues to be one of SAASTA's flagship projects. Our National Science Olympiad is not only able to contribute towards excellence in science, but has huge potential in heightening participation levels of previously excluded groups and simultaneously building their capability in the sciences.

The project offers learners in grades 10-12 an exciting opportunity to compete in the science arena with fellow learners from all the nine provinces and SADC countries, such as Namibia and Lesotho. The competition comprises an annual examination in science, and top learners and top schools stand a chance to win exciting prizes. The 2006 Olympiad comprised three sections: General Science Knowledge, Physical Science (Physics and Chemistry) and Biology. Whereas the General Science Knowledge section was compulsory, learners were given the option of writing either Physical Science or Biology. During the July vacation, a group of approximately 100 learners who excelled or demonstrated potential in the 2006 Olympiad examination, were invited to participate in a week-long science event consisting of stimulating lectures, industry visits and other fun events. The top national performers also stand a chance to win an all-expenses-paid trip to the London International

Youth Science Forum. This year three learners were selected to attend the 2006 London International Youth Science Forum during July/August.

Project Objectives

The following were identified as the objectives of the project:

- To identify and nurture talent in Science, Engineering and Technology.
- To recognise and reward learners who excel in the sciences.
- To motivate and encourage high performers and schools to engage with the sciences.
- To promote SET so that more learners study towards these careers in order to satisfy the demand for scientific human capital in the country.
- To expose learners to the SET fields, including careers and current trends.

2005

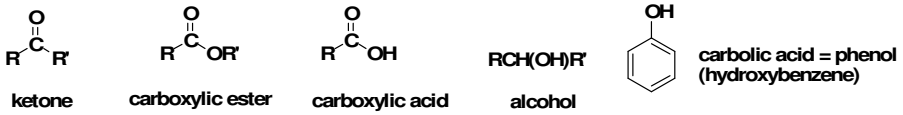
Note: Some of the questions are based on general chemistry knowledge and its bearing on daily life. The answers have been compiled from a variety of sources, mainly Wikipedia (the free online encyclopaedia), Encyclopaedia Britannica, the Kirk-Othmer Encyclopaedia of Chemical Technology and a variety of Chemistry textbooks. **TO DO WELL IN THE NATIONAL SCIENCE OLYMPIAD AND IN STUDYING AND PRACTICING SCIENCE, YOU MUST READ EXTENSIVELY!**

1. Glycerine is a/n……

1 ketone
2 carbolic acid
3 ester
4 alcohol

Answer:

Glycerine is another term for glycerol, a colourless, sweet, viscous liquid formed as a by-product in soap manufacture. It is used as an emollient and laxative, and for making explosives (nitroglycerin) and antifreeze. It is a trihydric alcohol of the chemical formula $CH_2(OH)CH(OH)CH_2(OH)$.
The functional groups in all the options above are depicted below. Note that carbolic acid is a special name given to phenol when used as a disinfectant (for example, in **Jeyes Fluid**!). Phenol is not a carboxylic acid but an alcohol!



2. In 1909 Sören Sörenson proposed the term pH to literally mean……

1 the potential of the hydrogen ion
2 the degree to which an acid ionizes
3 the degree to which a base ionizes
4 the equilibrium constant for an acid

Answer: Wikipedia

pH is a measure of the acidity of a solution in terms of activity of hydrogen ions (H^+). For dilute solutions, however, it is convenient to substitute the activity of the hydrogen ions with the molarity (mol/L) of the hydrogen ions (however, this is not necessarily accurate at higher concentrations).In aqueous systems, the hydrogen ion activity is dictated by the dissociation constant of water (K_w = 1.011 × 10^{-14} M^2 at 25 °C) and interactions with other ions in solution. Due to this dissociation constant, a neutral solution (hydrogen ion activity equals hydroxide ion activity) has a pH of approximately 7. Aqueous solutions with pH values lower than 7 are considered acidic, while pH values higher than 7 are considered basic. The concept was introduced by S.P.L. Sørensen in 1909, and is purported to mean "pondus hydrogenii" in Latin. However, most other sources attribute the name to the French term *pouvoir hydrogène.* In English, pH can stand for "hydrogen power," "power of hydrogen," or "potential of hydrogen." All of these terms are technically correct.

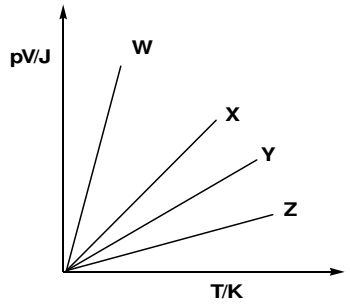
3. Methylcyclohexane is an important ingredient of ……..

1 glue
2 Prestik
3 Tippex
4 ink

Answer:

Methylcyclohexane, also called hexahydrotoluene is a colourless liquid with a faint benzene-like odour. It is used as a solvent and to manufacture organic chemicals. Among its uses, it is part of the liquid base for the all purpose liquid paper/correction fluid Tippex.

4. The relationship between pV and T for identical masses of 4 different gases W, X, Y and Z is shown in the graph below.



The gases could be:

	W	X	Y	Z
1	**neon**	**oxygen**	**carbon dioxide**	**chlorine**
2	oxygen	neon	chlorine	carbon dioxide
3	chlorine	carbon dioxide	oxygen	neon
4	carbon dioxide	chlorine	neon	oxygen

Answer:

From the ideal gas equation PV = nRT, When PV is plotted against T, you should get a straight line with a positive slope that equals nR (where R is the universal gas constant = $8.31JK^{-1}mol^{-1}$ and n stands for number of moles). The steepness of the slope will solely depends on the number of moles of each substance because R is a constant. The steeper/sharper the slope the higher the number of moles of substance available. You also know that n (number of moles) = m(mass)/ molar mass. This means that when there are equal masses of substances, the number of moles will differ depending on the molar masses of the substances. So, the higher the molar mass of a substance, the smaller its number of moles.

Let us answer the question e: There are four gases to be considered, Neon (Ne, 20.18 $gmol^{-1}$), Oxygen (O_2, 32.00 $gmol^{-1}$), carbon dioxide (CO_2, 44.01 $gmol^{-1}$) and chlorine (Cl_2, 70.90 $gmol^{-1}$) already arranged in increasing number of moles. Based on these molar masses, neon will have the steepest slope (**W**) while chlorine will have the shallowest (**Z**). **Option 1** is the only correct answer.

5. Study the following properties and then choose which gases have these properties.

a Collected by the upward displacement of air.

b Highly soluble in water

1 SO_2 and H_2S

2 SO_2 and HCl

3 HN_3 and HCl

4 SO_2 and NH_3

Answer: **CRC Handbook of Chemistry and Physics**

A gas heavier (denser) than air will stay at the bottom and displace air upwards. Comparing the densities of the above gases: at standard temperature and pressure (0 °C and 101.325 kPa), dry air has a density of 1.293 g/L. At standard ambient temperature and pressure (25 °C and 100 kPa), dry air has a density of 1.168 g/L. **Sulphur dioxide** has density of 2.551 g/L and water solubility of 9.4 g/100 mL (25 °C). **Hydrogen sulphide** has density of 1.363 g/L and limited water solubility. **Hydrogen chloride** has density 1.600 g/L and water solubility of 72 g/100 ml (20 °C). Ammonia has density of 0.747 g/L and water solubility of 89.9 g/100 mL. Thus, the correct combination of gases that are **both heavier than air and very water soluble is option 2**.

6. Oxidation will lead to ……..

1 an increase in the oxidation number of the oxidizing agent.
2 a decrease in the oxidation number of the oxidizing agent.
3 a decrease in the oxidation number of the reducing agent.
4 proton transfer between the oxidizing and reducing agent.

Answer:

During a redox reaction, the oxidizing agent (oxidant) gets reduced (its oxidation number is lowered) and the reducing agent (reductant) gets oxidized ((its oxidation number is increased). Oxidation means chemical reaction with oxygen or loss of electrons. Reduction means acceptance of electrons.

7. A solution of a certain salt forms a white precipitate with the solution of barium chloride that is insoluble in dilute hydrochloric acid. A solution of the same salt forms a white precipitate with hydrogen sulphide gas. The formula of the salt is …….

1 $CuSO_4$
2 $ZnSO_4$
3 $CuCl_2$
4 $ZnCl_2$

Answer:

From the general solubility trends in the table below, it is clear that the salt in question must be a sulfate since barium sulfate will not dissolve. Of the two options containing sulfates, reaction of copper sulfate with hydrogen sulfide will give black copper sulfide whilst reaction of zinc sulfate with hydrogen sulfide will give a white precipitate of zinc sulfide (sphalerite or wurtzite).

General Guidelines for the Solubility of Ionic Compounds in Water	
Soluble Compounds	**Exceptions**
Almost all salts of Na^+, K^+, and NH_4^+	
All salts of Cl^-, Br^-, and I^-	Halides of Ag^+, Hg_2^{2+}, Pb^{2+}
Salts of F^-	Fluorides of Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}
Salts of nitrate, NO_3^- chlorate, ClO_3^- perchlorate, ClO_4^- acetate, $CH_3CO_2^-$	
Salts of sulfate, SO_4^{2-}	Sulfates of Sr^{2+}, Ba^{2+}, Pb^{2+}
Insoluble Compounds	**Exceptions**
All salts of carbonate, CO_3^{2-} phosphate, PO_4^{3-} oxalate, $C_2O_4^{2-}$ chromate, CrO_4^{2-} sulfide, S^{2-} hydroxide, OH^- oxide, O^{2-}	Salts of NH_4^+ and the alkali metal cations

8. The anode of an electrochemical cell is made up of a metal that is placed in a solution of the metal salt. The metal …….

1 gains electrons and undergoes oxidation

2 gains electrons and undergoes reduction

3 loses electrons and undergoes oxidation

4 loses electrons and undergoes reduction

Answer:

The anode is the site for oxidation, i.e., electrons are lost to generate positively charged ions.

9. The following ionic equation represents the metal displacement reaction that takes place when a piece of copper metal is placed in a solution of silver nitrate

$$Cu + 2Ag^+ \rightarrow Cu^{2+} + 2Ag$$

The symbol of the oxidizing agent in this reaction is

1 Cu
2 Ag^+
3 Cu^{2+}
4 Ag

Answer:

An oxidizing agent is the electron acceptor in a (redox) reaction. In this process, it is reduced i.e., its oxidation state is lowered. A reducing agent is the electron donor. In the process, it gets oxidized, i.e., its oxidation state increases. In the above reaction, silver(I) (Ag^+) accepts electrons and gets reduced to silver metal (oxidation state zero). It is the oxidizing agent.

10. The pH of a solution of sodium hydroxide is 13. How will the [OH^-] and the pH of the solution be affected if distilled water is added to the solution?

	[OH^-]	**pH**
1	Decreases	Increases
2	**Decreases**	**Decreases**
3	Unchanged	Decreases
4	Increases	Decreases

Answer:

Adding distilled water dilutes the solution. This means the concentration of OH^- ions is reduced. Thus, pOH, which is $-\log[OH^-]$ is increased. From the relation between pH and pOH:

$$pH + pOH = 14$$

as pOH increases, pH decreases in compensation.

11. Two allotropes of carbon are…….

1 carbon dioxide and carbon monoxide

2 carbon -12 and carbon 1-14

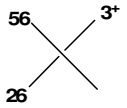
3 graphite and diamond

4 silicon and germanium.

Answer:

Allotrope means each of two or more different physical forms in which an element can exist. Graphite, charcoal, and diamond are all allotropes of carbon. Carbon 12 and Carbon 14 are **isotopes** of carbon. **Isotopes** are two or more forms of the same element that contain equal numbers of protons but different numbers of neutrons in their nuclei, and hence differ in relative atomic mass but not in chemical properties; in particular, a radioactive form of an element.

12. An isotope of an element can be represented symbolically as shown below.



The number of protons, neutrons and electrons represented are……

	protons	**neutrons**	**electrons**
1	30	26	29
2	26	30	29
3	30	26	23
4	**26**	**30**	**23**

Answer:

The top left number (56) represents the total number of nucleons (protons plus neutrons). The bottom left number (26) is the atomic number, which is equal to the number of protons. The number of neutrons is 56-26 = 30. The top right number (3+) is the oxidation number. That it is positive means three electrons were lost (oxidation). In a neutral/elemental state (oxidation state zero) of an element, the number of electrons equals the number of protons. Thus, with three electrons lost, the number of electrons left is 26-3 = 23. Based on this information, we can identify the ion, which is Fe^{3+}.

13. When reading the Periodic Table from left to right (i.e., from Li to F) there is …….

1 an increase in atomic radius since there is an increase in the number of valence electrons.

2 a decrease in atomic radius because there is an increase in the nuclear attraction for the valence electrons.

3 an increase in atomic radius since there is greater repulsion between the valence electrons

4 a decrease in atomic radius since gas atoms always occupy less space than metal atoms.

Answer:

The number of electrons increases across a period. The electrons are added into a pre-existing shell. The number of protons also increases. As a result, the nuclear charge is increased and since the number of shells were not increased, the effective nuclear charge (force of attraction) experienced by the added electrons is much greater, hence the decrease in atomic radius.

14. Which of the following substances will conduct electricity when molten but not in the solid state.

1 MgI_2

2 Cu

3 I_2

4 SiO_2

Answer:

Ionic solids in their molten state (heated until they melt) conduct electricity. An ionic solid (salt) is formed when two elements of vastly different electronegativities react. The only such substance given is magnesium iodide (MgI_2). Copper (Cu) is a metal and due to its metallic bond, will conduct electricity at all temperatures. Iodine (I_2) is a brittle solid containing pure covalent bonds and is a non-conductor. Silicon dioxide (SiO_2; quartz) also contains polar covalent bonds and at low temperatures, is a semiconductor. At high temperatures, it becomes a non-conductor. Computers/electronics contain silicon chips and are all equipped with fans to cool them down to maintain their conducting abilities!

15. Which of the solids given below sublimes upon heating?

1 Sodium

2 Phosphorus

3 Iodine

4 Ice

Answer:

Sublimation means changing directly from a solid into vapour when heated, typically forming a solid deposit again on cooling. Among the options given, only iodine sublimes. Phosphorus, sodium and ice all melt when heated.

16. The symbol Sn in the Periodic Table indicates the element……

1 zinc
2 tin
3 selenium
4 strontium

Answer:

Sn is symbol for element tin. It originates from late Latin *stannum*, which means tin. Study the periodic table for the symbols of the other given elements! Strontium (Sr) was named for its oxide, strontia, a white solid resembling quicklime (calcium oxide). It was named in the early 19th century from earlier strontian, denoting native strontium carbonate from Strontian, a parish in the Highland region of Scotland, where it was discovered.

17. Make use of your half-reaction table to predict which one of the following reactions needs addition of energy in order to take place.

1 $Zn + AgNO_3 \rightarrow$
2 $Zn + MgSO_4 \rightarrow$
3 $Al + CuSO_4 \rightarrow$
4 $Ni + Pb(NO_3)_2 \rightarrow$

Answer:

The reaction that will need energy to take place is non-spontaneous as written. The following equations give the products of the above reactions if they were to occur:

1. $Zn + AgNO_3 \rightarrow Zn(NO_3)_2 + 2Ag$ (zinc metal oxidized to Zn^{2+}; Ag^+ reduced to silver metal)
2. $Zn + MgSO_4 \rightarrow ZnSO_4 + Mg$ (zinc metal oxidized to Zn^{2+}; Mg^{2+} reduced to Mg^0 (metal)
3. $Al + CuSO_4 \rightarrow Al_2(SO_4)_3 + 3Cu$ (aluminium metal oxidized to Al^{3+}; Cu^{2+} reduced to metal)
4. $Ni + Pb(NO_3)_2 \rightarrow Ni(NO_3)_2 + Pb$ (nickel metal oxidized to Ni^{2+}; Pb^{2+} reduced to metal)

For the redox reaction in option 2:

$Zn + MgSO_4 \rightarrow ZnSO_4 + Mg$

The requisite standard reduction half potentials are:

$Zn^{2+} + 2e^- \rightarrow Zn$; $E^o = -0.763$ V and $Mg^{2+} + 2e^- \rightarrow Mg$; $E^o = -2.375$ V

As written in the equation, zinc is the reductant and gets oxidized whilst magnesium is the oxidant and gets reduced:

$\Delta E^o = E^o_{oxidant} - E^o_{reductant} = -2.375 - (-0.763) = -1.612$ V. The reaction is thus **non-spontaneous**! Using the standard reduction potentials table, calculate the cell potentials of the other three equations and they should all give **positive ΔE^o values (spontaneous!)**

18. Which of the following is the correct electron configuration for the ion Ca^{2+}?

1 $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$.

2 $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 4p^2$.

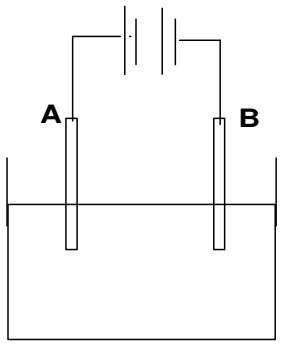
3 $1s^2 2s^2 2p^6 3s^2 3p^6$.

4 $[Ar]4s^2$.

Answer:

The cation Ca^{2+} results from oxidation of elemental calcium (loss of 2 electrons). Calcium has 20 electrons and upon oxidation, loses 2 electrons. Thus, for Ca^{2+}, there are only 18 electrons to distribute in all orbitals according to the Aufbau principle. **Only option 3 is correct**. Option 4 is incorrect because it is for elemental calcium with 20 electrons. Ca^{2+} has the same number of electrons as Argon and thus, the correct shorthand electron configuration would be $[Ne]3s^2 3p^6$.

19. A watery solution of copper chloride is placed in a container as indicated in the sketch. Two electrodes, A and B, are connected to the battery and placed in the solution.



Choose the assertion(s) below that are true.

(i) A is the anode
(ii) Chlorine gas forms at A
(iii) The copper cations move to B

1 Only (i)
2 Only (ii)
3 (i) and (ii)
4 (i), (ii) and (iii)

Answer:

There are two types of electrolytic cells; voltaic/galvanic and electrolytic. 1. A voltaic or galvanic cell produces electricity from a chemical reaction. 2. Electrolysis uses electricity to bring about chemical change. Regardless whether a cell is a voltaic or electrolytic cell; the anode (-ve electrode) is the electrode at which oxidation occurs and the cathode (+ve electrode) is the electrode at which reduction occurs. So, if the negative terminal is the electrode with greater concentration of electrons, then it serves as the anode in a voltaic cell and a cathode in an electrolytic cell. Conversely, the positive terminal is the cathode in a voltaic cell and an anode in the electrolytic cell.
Also remember the battery notation, ׀ ׀ ׀ ׀ ׀ ׀ the longer stick (׀) represents the positive terminal and the shorter stick (׀) the negative terminal of a cell. So the example shown above displays three cells connected in series to form a battery.

Electrolysis in aqueous media is complicated by the involvement of water. There is no doubt that we have Cu^{2+} and Cl^- ions in solution (due to the dissociation of $CuCl_2$) but water can either be oxidized or reduced as well. This suggests a need to compare two possible reduction half reactions and two possible oxidation half reactions. In each case **usually**, the $E°$ that is more positive in each case is taken (must consider which reaction is thermodynamically – which reaction has a more positive $E°$ favoured and which is kinetically favoured – how fast the reaction takes place).

Reduction half reactions

$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ $\quad E° = 0.34$ V

$2H_2O(g) + 4e^- \rightarrow H_2(g) + 2OH^-(aq)$ $\quad E° = -0.83$ V

In this case the choice is easy, copper ions will be reduced to copper metals rather than the reduction of water as the reaction that will take place at the cathode (the more positive $E°$).

Oxidation half reactions

$2Cl^-(aq) \rightarrow Cl_2(g) + e^-$ - $\quad E° = -1.36$ V

$6H_2O(l) \rightarrow O_2(g) + 4H_3O^+(aq) + 4e^-$ $\quad E° = -1.23$ V

This time, predictions based on voltage suggest the oxidation of water to oxygen. **But in practice, the reduction of chloride ions is favoured**!! Both thermodynamics and kinetic nature of reactions dictated

the products produced. Thermodynamics predicts which reaction is favoured and kinetics predicts which reaction occurs faster. In this case the oxidation of water is very slow compared to that of chloride ions. If the speed of reaction was to be factored in so that the direct thermodynamic comparison was made again, the reduction of water will carry an $E^\circ \approx$ -1.40V (slightly more negative than that of Cl^- = -1.36 V).This is generally termed overpotential or overvoltage and is especially apparent for reactions that involve gases such as H_2 and O_2.

This means that at the anode (where oxidation) takes place, the reaction

$2Cl^-(aq) \rightarrow Cl_2(g) + e^-$ - E° = -1.36 V occurs

And at the cathode (where reduction) takes place, the reaction

$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ E° = 0.34 V occurs.

The positive terminal (**A**) is the anode where oxidation of the chloride ions takes place and the negative terminal (**B**) is the cathode where the reduction of copper ions takes place. **Therefore option 4 is correct**.

20. Identify the type of chemical bonding and intermolecular forces in water.

	Chemical Bonding	**Intermolecular Forces**
1	Purely covalent	Van der Waals
2	**Polar covalent**	**H-bonds**
3	Ionic	H-bonds
4	Polar covalent	Van der Waals

Answer:

Because of the difference in electronegativities of oxygen and hydrogen, water molecules contain polar covalent bonds. Since the electron cloud is concentrated around the oxygen atom, the hydrogens are essentially without electrons and are hence protons. Hydrogen bonding, a weak intermolecular force, results from an electrostatic attraction between a proton in one molecule and an electronegative atom (oxygen) in the other.

21. A specific amount of dry gas is kept in a closed container at a temperature of 27 ºC. The volume is now halved and the pressure doubled. What will the temperature of the gas now be?

1 600 K
2 300 K
3 150 K
4 75 K

Answer:

From the ideal gas equation $pV = nRT$, we can calculate the effect of **halving the volume** and **doubling the pressure**:

$$2p \times 0.5V = nRT$$
$$pV = nRT$$

The factors cancel each other out, giving us the original equation. This means temperature is unaffected! Thus, the temperature will remain **27 ºC = 300 Kelvin!**

22. Two solutions, A and B, are both poured into a beaker thus forming a new solution. Here is more information on the first two solutions:

Solution A: 300 cm^3 of a 0.02 $mol.dm^{-3}$ $NaNO_3$ solution
Solution B: 400 cm^3 of a 0.01 $mol.dm^{-3}$ $Mg(NO_3)_2$ solution
What will the concentration of the nitrate ions in the new solution (in $mol.dm^{-3}$) be?

1 20
2 0.015
3 0.02
4 0.014

Answer:

First calculate the number of moles of nitrate ions in the original solutions:

Solution A: $c = n/v$

$n = cv = 0.02$ mol.dm^{-3} $\times$ 0.3 dm^3 = 0.006 mol

Solution B: $c = n/v$

$n = cv = 2 \times 0.01$ mol.dm^{-3} $\times$ 0.4 dm^3 = 0.008 mol

[Magnesium nitrate ($Mg(NO_3)_2$ gives two moles of nitrate ions upon dissolution!)]

After mixing:

The total volume becomes 300 + 400 = 700 cm^3 = 0.7 dm^3

The total number of moles of nitrate ions is 0.008 + 0.006 = 0.014 moles.

The new concentration of nitrate ions is:

$c = n/v$ = 0.014 moles/0.7 dm^3 = **0.02 M**

23. A 300 cm^3 solution with a concentration of 0.03 mol.dm^{-3} needs to be diluted to a concentration of 0.005 mol.dm^{-3}. How much water must be added to achieve this?

1 1800 cm^3

2 1500 cm^3

3 50 cm^3

4 1.8 dm^3

Answer:

The initial (1) and final (2) concentrations are related by the equation:

$c_1v_1 = c_2v_2$

The final volume is : $c_1v_1 / c_2 = v_2$

$v_2 = 0.300$ dm^3 $\times$ 0.03 mol.dm^{-3}/ 0.005 mol.dm^{-3} = 1.8 dm^3

To achieve this volume, we need to add 1.5 dm^3 = 1500 cm^3 of water. This will give us the desired concentration of 0.005 M.

24. Sulphur dioxide can act as an oxidizing and as a reducing agent. As what does it act in reaction with……..

	In reaction with	**Acts as a(n)**
1	Water	Oxidizing agent
2	Magnesium	Reducing agent
3	Potassium dichromate	Oxidizing agent
4	**Hydrogen sulphide**	**Oxidizing agent**

Answer:

In water, sulfur dioxide dissolves to give sulphurous acid:

$SO_2 + H_2O = H_2SO_3$.

The oxidation state of sulfur has changed from 4+ to 6+. This is an oxidation reaction.

In the presence of moisture, sulfur dioxide reacts with magnesium to give magnesium sulphite:

$Mg^+ SO_2 + H_2O = MgSO_3 + H_2$.

This is the same as reaction sulfur dioxide first with water (an oxidation reaction!) then the resultant acid with magnesium. Magnesium has been oxidized from the metallic state to Mg^{2+} cation. The oxidation state of sulfur (+6 as sulphite) has not changed but instead, hydrogen from water has been reduced from H^+ to H_2 gas.

In reaction with potassium dichromate, sulfur dioxide gets converted (oxidized) to the sulfate ion:

$K_2Cr_2O_7 + H_2O + 4SO_2 = K_2SO_4 + Cr_2(SO_4)_3 + H_2$

The oxidation state of sulfur has increased from +4 to +6. This is a redox reaction, and **sulphur dioxide** acts as a **reducing agent**.

In the presence of moisture, **sulphur dioxide oxidises** hydrogen sulfide according to the equation:

$SO_2 + 2H_2S = 2H_2O + 3S$

25. In general, nitrates are thermally unstable; when heated, the compounds break down. In which one of the following cases are the correct products given for the breakdown of the nitrate listed?

	Nitrate	**Products**
1	KNO_3	$K_2O + NO_2 + O_2$
2	$Pb(NO_3)_2$	$PbO + NO_2 + O_2$
3	**HNO_3**	**$NO_2 + H_2O$**
4	NH_4NO_3	$NH_3 + N_2O$

Answer:

The first two options and the last are not balanced chemical equations and thus easy to dismiss! The third option is correct. Nitric acid is indeed made by bubbling nitric oxide in water and when heated, it slowly decomposes back to water and nitric oxide. For option 4, the correct decomposition products for ammonium nitrate (a powerful explosive!) are:

$$NH_4NO_3 \rightarrow N_2 + 2H_2O + ½\ O_2$$

26. In the reaction of potassium permanganate with hydrochloric acid, both oxidation and reduction occur. Choose the option which has the correct half-reaction for oxidation and for reduction.

	Oxidation half-reaction	**Reduction half-reaction**
1	**$2Cl^- \rightarrow Cl_2 + 2e^-$**	**$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$**
2	$2Cl^- \rightarrow Cl_2 + 2e^-$	$2H^+ + 2e^- \rightarrow H_2$
3	$K \rightarrow K^+ + 2e^-$	$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$
4	$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$	$2Cl^- \rightarrow Cl_2 + 2e^-$

Answer:

In the reaction of potassium permanganate ($KMnO_4$), manganese is always involved in the electron exchange, getting reduced. On the basis of this, option two is incorrect since there is no Mn^{7+} involved. Since potassium came already as a cation (its highest oxidation state), it cannot be involved in the redox process and thus option 3 is also incorrect. In option four, Mn^{7+} is converted to Mn^{2+}, which is reduction, not oxidation and Cl^- to Cl_2, which is oxidation! Thus, the correct option is the first!

2006

1. Consider a mixture consisting of sand in sugar water. How can this be separated into sand, sugar and water? First ___ and then ___

1 distilling, distilling

2 distilling, filtering

3 filtering, filtering

4 filtering, distilling

Answer:

Filtration is the separation of solid particles from a fluid + solid suspension (heterogeneous mixture consisting of solid and liquid phases clearly visible) of which they are a part by passage of most of the fluid through a septum or membrane (like filter paper) that retains most of the solids on or within itself. Distillation is the evaporation and subsequent collection of a liquid by condensation as a means of purification. Distillation is a method for separating homogeneous mixtures based upon equilibration of liquid and vapor phases. Substances that differ in volatility appear in different proportions in vapor and liquid phases at equilibrium with one another. We answer the question as follows:

Option 1 is incorrect; this will leave behind sugar and sand as solids in the first distillation process. 2 is incorrect, same reasoning as above. 3 is incorrect, only sand particles will be separated by the technique used here. **Option 4 is Correct**, filtering removes sand particles (heterogeneous mixture made up of sugar solution and sand), and distillation will result in water being separated from sugar (homogeneous sugar solution, different physical properties).

2. Which one of the following elements has the element name and symbol correctly matched?

1 P, Potassium

2 C, Copper

3 Mg, Manganese

4 Ag, Silver

Answer:

Check the Periodic Table for details. Assessment of each option is done as follows:

Option 1 is incorrect, symbol for potassium is K and P is the chemical symbol for the element phosphorus. 2 is incorrect, C is the symbol for the element carbon, while the symbol for copper is Cu. 3 is incorrect, Mg is the symbol for the element magnesium, the symbol for manganese is Mn. **Option 4 is correct**.

3. Which states of matter is/are significantly compressible?

1 Gases only

2 Liquids only

3 Solids only

4 Liquids and gases

Answer:

In physical science, **compressibility** is a measure of the relative volume change of fluid (gas and liquid) or solid as a response to a pressure change. Thus a substance is compressible if its volume decreases when pressure is applied. Only gaseous and liquid substances can be compressed. In fact, gaseous substances are the easiest to compress. Let us rationalize this phenomenon based on microscopic features of the three phases of matter (solid, liquid and gas). In a solid, atoms or molecules are in close contact, thus they occupy a definite volume and have definite shape, meaning that atoms or molecules have restricted movement, hence non-compressible. In a liquid, the atoms or molecules are separated by greater distances than in a solid. This allows movement of atoms or molecules (called fluidity) hence partially compressible. In a gas, the distance between atoms or molecules is much greater than in a liquid. This allows the gas to expand and fill its container, making this state of matter greatly compressible. We thus answer the question as follows:

Option 1 is correct, as only gases are 'significantly' compressible. 2 is incorrect, liquids are infinitesimally compressible. 3 is incorrect solids are not compressible at all. 4 is incorrect, check reasoning for choice B.

4. The nucleus of an atom contains

1 electrons

2 protons

3 protons and electrons

4 protons and neutrons

Answer:

An atom consists of a dense nucleus surrounded by an electron cloud. The nucleus is composed of two nucleons (protons, that are positively charged, and neutrons, which are neutral or uncharged) while the electron cloud is occupied by electrons (negatively charged). These three (proton, neutron and electrons) are the only sub-atomic particles that you are required to know at this stage. We thus answer the question as follows:

Option 1 is incorrect, electrons are found in the electron cloud that envelopes the nucleus. 2 is incorrect, the other nucleons, neutrons are also found in the nucleus. 3 is incorrect, check reasoning for choice 1 above. **Option 4 is correct**, the two types of nucleons are found in the nucleus of an atom.

5. Which pair of elements would you expect to exhibit the greatest similarity in physical and chemical properties?

1 0, S

2 C, N

3 K, Ca

4 H, He

Answer:

Similarities in both physical and chemical properties are for elements that are in the same group or family in the Periodic Table of elements. Elements in the same group in the Periodic Table have similar electron configurations, e.g., group I and VII elements have the outer-shell electron configurations ns^1 and ns^2np^5 respectively, where n is the principal quantum number or period. This means that the reactivity patterns of elements in the same group will be similar because they will have the same number of valence electrons (electrons involved in bonding) regardless of the period where they are found.

Option 1 is correct, both elements are in the same group in the Periodic Table of elements. 2 is incorrect, carbon is in group IV while is nitrogen in group V, leading to different chemical properties. 3 is incorrect; potassium and calcium are in different groups. 4 is incorrect hydrogen and helium are in different groups.

6. Which of the following has 16 protons?

1 ^{31}P

2 $^{34}S^{2-}$

3 $^{80}Br^-$

4 ^{36}Cl

Answer:

The Periodic Table of the elements is arranged periodically (discernable trends) according to increasing atomic number. The atomic number (Z) is the identity of the element and it always equals the number of protons of the element. This means that if you know the total number of protons, you know the element. The number of neutrons of an element may vary giving rise to isotopes. The number of electrons of an element may also change giving rise to ions (cations if electrons are removed and anions if electrons are added). If however, the number of protons is altered in anyway (removal or addition), you end-up with a different element!! We thus answer the question as follows: the number of

protons is given as 16 corresponding to the element sulphur (S), which is the only one in the Periodic Table that has 16 protons. The question can thus be answered as follows:

Option 1 is incorrect, it has 15 protons; **2 is correct**, element number 16; 3 is incorrect, it has 35 protons and 4 is incorrect, it has 17 protons

7 Which pair of elements is most likely to form an ionic compound with each other?

1 barium, bromine

2 calcium, sodium

3 oxygen, fluorine

4 sulphur, fluorine

Answer:

Ionic bonding (interaction) arises when a metal and a non-metal interact. This kind of bonding (where electrons are transferred from a metal to the non-metal) exists because of the vast difference in electronegativity values between the two atoms that interact. If the electronegativity difference is small, as is the case when two non-metals interact, then sharing of electrons will take place, commonly referred to as **covalent bonding**. The type of bonding that takes place when metals are involved is referred to as **metallic bonding**. Note that metallic bonding holds the atoms of metals together, in their elemental state and gives them the unique properties of ductility, malleability and good thermal and electrical conducting abilities. Metals rarely react with each other to form bonds; instead, they mix to form solid solutions called alloys. Assessment of the options given is as follows:

A is correct, the alkali metal Barium will react with bromine, a halogen, to form barium bromide (BaBr) held together by ionic bonds. B is incorrect, metal-metal interaction, they will not bond but at high temperatures will dissolve in each other to form an alloy. C is incorrect, non-metal and non-metal interaction, covalent bonding and D is incorrect, non-metal and non-metal interaction, covalent bonding.

8. The formula of bromic acid is:

1 HBr

2 $HBrO_4$

3 $HBrO_3$

4 HBrO

Answer:

The key to answer this kind of question is to memorise the table of ions given (Chemical Bonding Chapter). **You are expected to know the ions given by heart!** There are few basic rules that you need

to remember pertaining to oxyanions (binary anions that contain oxygen, like SO_4^{2-}, NO_3^- MnO_4^- $Cr_2O_7^{2-}$ etc). If there are two oxyanions of the same element, the ion with more oxygen has the suffix –ate in naming, while the other has –ite (SO_4^{2-} sulphate (sulfate) and SO_3^{2-} is a sulphite (sulfite). If there are more than two oxyanions of the same element, then prefix per- denotes the anion that has one more oxygen than the –ate while the prefix hypo- is used to name the anion with one less oxygen that

the -ite. This is highlighted below (BrO_4^- is perbromate, BrO_3^- is bromate, BrO_2^- is bromite and BrO^- is hypobromite ion). The acid equivalent of oxyanions is such that anions that have the suffix –ite are always named –ous acids while those with –ate suffix are named –ic acids. So $HBrO_4$ that comes from perbromate ions is termed perbromic acid and HBrO that comes from hypobromite is termed hypobromous acid.

Option 1 is incorrect, this is hydrobromic acid (or hydrogen bromide in the gaseous state.) 2 is incorrect, this is perbromic acid. **Option 3 is correct**. 4 is incorrect, this is hypobromous acid.

9. If molecular formulas are integer multiples of the empirical formulas, then the empirical formula of a compound with molecules containing 12 carbon atoms, 14 hydrogen atoms and 6 oxygen atoms is:

1 $C_{12}H_{14}O_6$

2 CHO

3 CH_2O.

4 $C_6H_7O_3$

Answer:

A **molecular compound** is a compound comprised of discrete molecules. The **empirical formula** of a compound is the simplest formula (ratio) of atoms comprising the compound. This means that you would have the simplest whole number ratios that cannot be divided by two when you have an empirical formula. A **molecular formula** is based on the actual molecule of a compound. For an example, the molecular formula of acetic acid is $C_2H_4O_2$ while its empirical formula is CH_2O. In most instances the molecular formula is a multiple of the empirical formula, in the example given above; it is twice the empirical formula. In certain instances the molecular and empirical formulas are identical as in H_2O (water). Based on these descriptions, we answer the question as follows:

Option A is incorrect, molecular formula is given, as the numbers 12, 14 and 6 are divisible by 2. B is incorrect, wrong empirical formula deduced. C is incorrect, wrong empirical formula deduced. **D is correct**, simplest combination of integers representing the number of atoms making up a molecule, i.e., when 12, 14 and 6 are divided by 2 you get 6, 7 and 3 respectively.

10. Element T is in group IA, element X is in group IIA, element Y is in group VIA and element Z is in group VIIA of the Periodic Table. A formula for the compound formed by two of these elements that is INCORRECT, which formula is that?

1 TZ

2 XY

3 T_2Y

4 X_2Y

Answer:

Valency is the bonding power of an element and is periodic, particularly for main group elements. This means that elements in the same group have the same valency. Groups I, II, III and IV have valences 1, 2, 3 and 4 respectively (valency equals group number). Groups V, VI, VII and VIII have valences 3, 2, 1 and 0 respectively (valency equals 8 minus group number in this case). When compounds are formed, the valency of the elements involved dictates the product formed. The 'imaginary charges' must be equalized to form a stable species. For example, if a group I element (valency = 1,or say +1 as it involves metals that tend to give electrons) interacts with group VI (valency = 2 or say -2 as usually non-metals accept electrons) then the product must have two group I elements to one group VI element so that 2 × 1 equals 1 × 2 etc. The question can thus be answered as follows:

Option 1 is correct, valencies are 1 and -1. 2 correct, valencies are 2 and -2. 3 correct, valencies are 1 and -2. **Option 4 is incorrect**, valencies are 2 and -2.

11. What is the general formula for an organic acid?

1 $R\text{-}CH_2\text{-}OH$

2 R-O-R

3 R-C=O

4 R-C=O

Answer:

An **organic acid** is an organic compound with acidic properties. The most common organic acids are the carboxylic acids whose acidity is associated with their carboxyl group -COOH. Sulfonic acids, containing the group OSO_3H, are relatively stronger acids. Other groups can also confer acidity, usually weakly: hydroxyl group -OH, -SH, and the phenol group. The question can be answered as follows;

A is correct, this formula is for alkoxide or alcohol, which are weakly acidic. B is incorrect, this formula is for ethers. C is incorrect, the formula is incomplete; we do not know whether this would have been an aldehyde, R-COH, ketone, R-CO-R, amide, $R\text{-}CO\text{-}NH_2$ or an acid $R\text{-}CO_2H$. D is incorrect, same reasoning as in C above.

Note: at your level the general formula for an organic acid specifically refers to carboxylic acids (R-CO_2H) examples are acetic acid, CH_3COOH butyric acid, $CH_3(CH_2)_2COOH$, maleic acid, HOOCCHCHCOOH, and benzoic acid, C_6H_5COOH. This option was not made available however.

12. Which of the following reactions below is a decomposition reaction?

1 $NH_4Cl \rightarrow NH_3 + HCl$

2 $2Mg + O_2 \rightarrow 2MgO$

3 $Cd(NO_3)_2 + Na_2S \rightarrow CdS + 2NaNO_3$

4 $2N_2 + 3H_2 \rightarrow 2NH_3$

Answer:

In simple terms, chemical reactions can be classified into three types based on the number of reactants and products. 1. **Synthesis reactions** (A + B → C) where two or more reactants react to form fewer products, in this example, two reactants yield one product. 2. **Metathesis or exchange/dismutation reactions** (A + B → C +B) where the number of reacts equals the number of products formed. 3. **Decomposition reactions** (A → B +C) where the numbers of products are always more than the number of reactants, usually, one reactant decomposes to give two or more products. The question can thus be answered as follows:

1 correct, two products arise from a single reactant. 2 incorrect, the reaction shown is synthesis. 3 incorrect, the reaction shown is metathesis (exchange reaction). 4 incorrect, again a synthesis reaction is shown.

13. Of the following, which is not true concerning automotive air bags?

1 They are inflated as a result of decomposition reaction

2 They are loaded with sodium azide initially

3 The gas used for inflating them is Oxygen

4 The two products of the decomposition reaction are sodium and nitrogen

Answer: For years, the trusty seat belt provided the sole form of passive restraint in cars. Statistics have shown that the use of seat belts has saved thousands of lives that might have been lost in collisions. Air bags have been under development for many years and come standard in many car models as extra devices to protect a driver and passengers when a collision occurs. How does an airbag work? Before looking at specifics, let's review our knowledge of the laws of motion. First, we know that moving objects have momentum (the product of the mass and the velocity of an object). Unless an outside force acts on an object, the object will continue to move at its present speed and direction. Cars consist of several objects, including the vehicle itself, loose objects in the car and, of course, passengers. If these objects are not restrained, they will continue moving at whatever speed the car is traveling, even if the car is stopped by a collision.

Stopping an object's momentum requires force acting over a period of time. When a car crashes, the force required to stop an object is very great because the car's momentum has changed instantly while the passengers' has not -- there is not much time to work with. The goal of any supplemental restraint system is to help stop the passenger while doing as little damage to him or her as possible. What an air bag is intended to do is to slow the passenger's speed to zero with little or no damage. There are three parts to an air bag that help to accomplish this feat: 1.The bag itself is made of a thin, nylon fabric, which is folded into the steering wheel or dashboard or, more recently, the seat or door. 2. The sensor is the device that tells the bag to inflate. Inflation happens when there is a collision force equal to running into a brick wall at 10 to 15 miles per hour (16 to 24 km per hour). A mechanical switch is flipped when there is a mass shift that closes an electrical contact, telling the sensors that a crash has occurred. The sensors receive information from an accelerometer built into a microchip. 3. The air bag's inflation system triggers sodium azide (NaN_3) which decomposes to produce nitrogen gas. Hot blasts of the nitrogen inflate the air bag. The question can thus be answered as follows:

Option 1 is correct, decomposition of sodium azide. 2 is correct; sodium azide is loaded into the airbag. 3 is incorrect; this gas supports combustion and may accelerate fire during an accident. 4 is correct; sodium is produced as a by-product during the decomposition of NaN_3.

14. A 0.200 M K_2SO_4 solution is produced by

1 dilution of 250.0 mL of 1.00 M K_2SO_4 to 1.00 L.

2 dissolving 43.6 g of K_2SO_4 in water and diluting to a total volume of 250.0 mL

3 diluting 20.0 mL of 5.00 M K_2SO_4 solution to 500.0 mL

4 dissolving 20.2 g of K_2SO_4 in water and diluting to 250.0 mL, then diluting 25.0 mL of this solution to a total volume of 500.0 mL

Answer:

Here the basics of solution preparations and calculations are applied. We thus assess each option as follows:

Option 1 is incorrect because the resulting solution has a concentration of 1.00 M × 0.25 l/1.00 L = 0.25 M. Option 2 is incorrect because the resulting solution has a concentration of 43.6 g/(174.26 $g.mol^{-1}$)(0.25 L) = 1.00 M. **Option 3 is correct**, concentration = 20.0 mL × 5.00 M/500.0 mL = 0.25 M. 4 is incorrect, original solution (before dilution) has a concentration of 20.2 g/(174.26 $g.mol^{-1}$ × 0.25 L) = 0.464 M. The diluted solution has a concentration value of 25.0 mL × 0.464 M/500 mL = 0.023 M.

15. What is the concentration (M) of NaCl in a solution made by mixing 25.0 mL of 0.100 M NaCl with 50.0 mL of 0.100 M NaCl?

1 0.100

2 0.0500

3 0.0333

4 0.0250

Answer:

Here the same solution (identical concentration values given) which means the resulting solution (when the two identical solutions are mixed) will have the same concentration. It is like when you have dissolved say two spoonfuls of sugar in a cup and you then draw a little to taste. The concentration of the solution you swallowed is the same as that in the cup. There is no need to do calculations. If however you want to do calculations, this is the way to approach it:

Adding 25.0 mL to 50.0 mL gives a final volume of 75.0 mL which is 75.0/1000 = 0.075 liters

Now calculate the number of moles of NaCl in the volumes before the two solutions were added.

In 25.0 mL, you had

$c = n/v$; $n = cv$ = 0.100 moles per litre × 25.0 mL/1000 mL per liter = 0.0025 moles.

In 50.0 mL, you had

$c = n/v$; $n = cv$ = 0.100 moles per litre × 50.0 mL/1000 mL per liter = 0.0050 moles.

The final concentration after mixing will be the sum of the above number of moles divided by total volume:

$c = n/v$ = 0.0025 + 0.0050 moles/0.075 litres = 0.100 M!

Please note that **you cannot use formula $c_1v_1 = c_2v_2$,** where c and v stand for concentration and volume. This formula is only for solutions which are diluted with pure solvent. We answer the question as follows:

Option 1 is correct, same concentration before and after addition of the two. 2 is incorrect; this suggests a dilution factor of 2, meaning the solution was added to an equal amount of diluent (usually water). 3 is incorrect; this suggests a dilution factor of 3, meaning the solution was added to two parts of diluent (water). 4 is incorrect, dilution factor of 4, this would have been the case if one part of original solution was added to 3 parts of diluent (water).

16. Which one of the following is an exothermic process?

1 ice melting

2 water evaporation,

3 boiling soup,

4 condensation of water vapour

Answer:

An exothermic process gives out heat while an endothermic process requires heat to take place. The phase changes (melting, boiling and sublimation) require energy (heat) and are endothermic processes while the reverse (freezing and condensation) release heat and are thus exothermic processes. Evaporation is a surface phenomenon whereby a molecule in a liquid state escapes into gas state at temperatures below the boiling point of the liquid. Temperature is defined as a measure of the average kinetic energy of a substance. This means that there are molecules of a substance that have higher kinetic energies than the average (similarly those that have less kinetic energy than the average). This statement suggests that molecules of a substance have different kinetic energies although the temperature reading may be constant!! Therefore molecules that have sufficiently high kinetic energy that may happen to be at the surface of the liquid can escape to the gaseous state, such that the average kinetic energy of the remaining molecules drops. Note that within the body of the liquid there may also be other molecules that have sufficient kinetic energy but they are unable to escape because they are restricted by the neighboring molecules. Using the information above we assess each option given as follows:

Option 1 is incorrect; heat is required (endothermic process). 2 is incorrect, heat is required (endothermic process). 3 is incorrect, same reasoning as in 1 and 2 above. **Option 4 is correct**; heat is given off during condensation.

17. Which one of the following is not considered a fossil fuel?

1 petroleum

2 natural gas

3 crude oil

4 hydrogen

Answer:

Petroleum (crude oil), natural gas and coal are the only fossil fuels in use to date. Hydrogen is one of the elements known.

18. The _____ sub-shell contains only one orbital.

1 5d

2 1p

3 4s

4 6f

Answer:

There are 4 types of sub-shells, s sub-shell (always has one orbital), p sub-shell (always has 3 orbitals), d- sub-shell (always has 5 orbitals) and f sub-shell (always has 7 orbitals). The number of orbitals in each sub-shell is constant regardless of the energy level (the number in front of the sub-shell) where the sub-shell is found. Using this information, we assess each option given as follows:

Option1 is incorrect because a d sub-shell contains 5 orbitals. 2 is incorrect because a p-sub-shell contains 3 orbitals. In fact the sub-shell designation, 1p is forbidden. You get p-sub-shells when the principal quantum number is 2 and above, i.e., 2p, 3p, etc. **Option 3 is correct** as you have an s-sub-shell in the fourth energy level (n = 4) that has one orbital. 4 is incorrect because an f sub-shell has seven orbitals.

19. The electron configuration of the S^{2-} ion is

1 $[Ar]3s^2 3p^6$

2 $[Ar]3s^2 3p^2$

3 $[Kr]3s^2 2p^{-6}$

4 $[Ne]3s^2 3p^6$

Answer:

The notation shown above is referred to as the condensed electron configuration. In this notation, the element in squared brackets is the noble gas element preceding the element considered, denoting core electrons (electrons that are not involved in bonding). Outer shell electrons (that includes valence electrons) are then placed in the valence orbitals taking into consideration the charge of the species involved (atom, molecule ion). For example, all elements in period 3 and 4 will have He and Ne respectively in squared brackets etc. Therefore the question can be answered as follows:

S^{2-} (element sulfur gas 16 electrons and we add the two for its charge to get 18 electrons) has the same electron configuration as Ar i.e., $[Ne]3s^2 3p^6$ (option 4). When dealing with the element sulfur (S) the preceding noble gas element is neon (Ne) not Ar as option 1 suggests. Both Kr and Ar are noble gas elements that are beyond sulfur.

20. The type of compound that is most likely to contain a covalent bond is ____?

1 one that is composed of a metal from far left of the Periodic Table and a nonmetal from the far right of the Periodic Table

2 a solid metal

3 **one that is composed of only nonmetals**

4 held together by the electrostatic forces between oppositely charged ions

Answer:

Ionic bonding arises when a metal interacts with a non-metal, covalent bonding arises when two non-metals interact and metallic bonding arises when only a metal(s) is/are involved (this was explained in details earlier). Based on this explanation **option 3 is the correct choice**. Option 2 is for a metallic bonding and Options 1 and 4 relate to ionic bonding.

21. Consider the following species:

i. PCl_3

ii. CH_2Cl_2

iii. HCN

iv. C_2H_4

v. NH_3

In the Lewis structures of _____, the central atom has one lone pair of electrons

1 (i) only

2 (i) and (iii)

3 (i) and (iv)

4 **(i) and (v)**

Answer: The Lewis structures of CH_2Cl_2 (tetrahedral geometry), HCN (linear geometry) and C_2H_4 (trigonal planar around each carbon atom) do not have lone pairs on the central atoms. Both PCl_3 and NH_3 have one lone pair around the central atoms resulting in (trigonal) pyramidal geometry. Option 4 agrees with the information given above.

22. The molecular geometry of the SF_2 molecule is _____

1 linear

2 **bent**

3 tetrahedral

4 trigonal planar, three bonding domains, no lone pairs.

Answer:

There are two lone pairs on the central atom (sulfur) in addition to the two bonding domain resulting in four electron sites. The lone pairs occupy more space than the bonding pairs resulting in a bent

(angular) geometry. Option 2 is thus correct. If there are two bonding domains with no lone pairs around the central atom, the geometry is called linear (option 1). If there are four bonding domains with no lone pairs around a central atom, the geometry is called tetrahedral. If the are three bonding domains around the central atoms and there are no lone pairs the geometry is referred to as trigonal planar (option 4).

23. A balloon originally had a volume of 4.39 L at 44 °C and a pressure of 729 torr. The balloon must be cooled to _____ °C to reduce its volume to 3.78 L (at constant pressure).

1 38

2 0

3 72.9

4 273

Answer:

From the general gas equation $PV = nRT$, if the amount of gas is kept constant then $V_1/T_1 = V_2/T_2$ at constant pressure (Charles' law). Therefore $T_2 = T_1 \times V_2/V_1 = 38$ °C. There is no basis to choose any of the other three options.

24. An ideal gas differs from a real gas in that the molecules of an ideal gas ___?

1 have no attraction for one another

2 have appreciable molecular volumes

3 have a molecular weight of zero

4 have no kinetic energy.

Answer:

The principal tenets (beliefs) of ideal gas are summarized by the kinetic molecular theory which states that (a) gases consists of molecules/atoms whose volume is negligible compared to the total volume of the gas, (b) the molecules are in continual, random motion and they collide with each other and the sides of the container without energy transfer (i.e., they bounce off in a totally elastic manner, (c) their average kinetic energy is determined by the temperature and (d) there are no forces of attraction between the molecules. We can answer the question as follows:

Option 1 is correct, real gas molecules have weak van der Waals' attractions. 2 is incorrect, only real gas molecules have volumes and occupy space. 3 is incorrect, real gases have mass. 4 is incorrect, real gases being in constant Brownian motion have kinetic energy.

25. As a solid element melts, the atoms become _____ and they have _____ attraction for one another.

1 more separated, more

2 more separated, less

3 closer together, more

4 closer together, less

Answer:

As solids melt, the forces of attraction between the atoms are weakened and the atoms are now free to move about in the liquid state that results. Degree of freedom in terms of atom/molecule mobility increases from solid (rigid structure where atoms/molecules only vibrate) to liquid (where atoms/molecules diffuse) and finally to gases (where Brownian motion takes place). This implies that the force of attraction between atoms/molecules in the gaseous state is less compared to liquids and solids. Option 2 is thus correct.

26. What is the pH of an aqueous solution at 25 °C in which $[H^+]$ is 0.025 M?

1 +3.40

2 +2.60

3 -2.60

4 -3.40

Answer: $pH = -\log[H^+]$. The pH values encountered start from 0 (acidic) to 14 (basic). **By definition, you cannot have negative pH values (at your level).** Options 3 and 4 are not appropriate for this question. Therefore $pH = -\log(0.025) = 1.6$ (none of the options given is correct!!. Let us look at the options A and B to see why they are also wrong.

1 incorrect, $pH = -\log[H^+]$, therefore $[H^+] = 10^{-pH} = 0.005M$. 2 is also incorrect, $pH = -\log[H^+]$, therefore $[H^+] = 10^{-pH} = 0.0025M$

27. Which of the following solutions has the highest concentrations of hydroxide ions?

1 pH = 3.21

2 pH = 12.59

3 pH = 7.93

4 pH = 9.82

Answer:

The most basic solution has the highest OH^- concentration indicated by a higher pH value. A lower pH value means a solution that is more acidic. **Option 2** has the highest pH reading and is thus the **correct** option.

28. Select the substance that is thought to be partially responsible for depleting the concentration of ozone in the stratosphere.

1 $CFCl_3$

2 CO_2

3 O_2

4 N_2

Answer: Substances that deplete ozone are commonly referred to as CFCs (Chloro-fluoro carbons), of which option 1 is one. The other three are harmless gases freely available in the atmosphere (note that increasing amount of CO_2 in the atmosphere contributes towards global warming).

29. What is the coefficient of the permanganate ion when the following equation is balanced?

$MnO_4^- + Br^- \rightarrow Mn^{2+} + Br_2$ (acidic solution)

1 1

2 2

3 3

4 5

Answer: Look for the two half-reaction (MnO_4^-/Mn^{2+} and Br^-/Br_2) in the **reduction half potentials table that is given**. The MnO_4^-/Mn^{2+} half reaction involves 5 electrons while Br^-/Br_2 half reaction involves 2. The former is multiplied by 2 and the latter by 5 to equalize the number of electrons rendering option 2 correct.

30. What is a phosphor?

1 an oxide of phosphorus

2 a substance that thermally reduces phosphorus

3 a bioluminescent substance

4 a substance that emits light when excited by radiation

Answer: Option 1 is incorrect; an oxide of phosphorus is simply phosphorous oxide. 2 is also not correct because there is no special name for such a substance. 3 is incorrect because a bioluminescent refers to emission of visible light by living organisms such as the firefly and various fish, fungi, and bacteria. **Option 4 is correct** because a phosphor is a chemical substance that exhibits fluorescence when excited by radiation.

31. Which one of the following forms of radiation can penetrate the deepest into body tissue?

1 alpha

2 beta

3 gamma

4 positron

Answer:

Option 1 is incorrect: An **alpha particle** consists of two protons and two neutrons, the equivalent of the nucleus of a helium atom. Alpha particles do not penetrate the outer layer of human skin. 2 is incorrect: A **beta particle** is an electron or a positron and is much lighter than an alpha particle. It travels about one millimeter into body tissue. **Option 3 is correct**: **Gamma rays** are very short wavelength, high energy (ionizing) electromagnetic radiation. Gamma rays can penetrate much more deeply into matter and in living cells, will cause damage to nuclear/genetic material (DNA) leading to cancer or cell death. Option 4 is incorrect; a positron is a subatomic particle with the same mass as an electron and a numerically equal but positive charge.

32. The oxidation numbers of sulfur in the sulfate ion, sulfite ion, sulfur trioxide and hydrogen sulfide are _____, _____, _____ and_____, respectively

1 +4, -2, +4, +6

2 +6, +2, +4, +6

3 +6, +4, +6, -2

4 +4, +6, +4, -2

Answer:

You must memorize the table of ions found in The Chemical Bonding Chapter. The oxidation states are sulfate ion (SO_4^{2-}) = +6, sulfite ion (SO_3^{2-}) = +4, sulfur trioxide (SO_3) = +6, hydrogen sulfide (H_2S) = -2. **Option 3 is the only one correct**.

33. The primary commercial use of elemental nitrogen is in the manufacture of?

1 plastics

2 explosives

3 nitrogen-containing fertilizers

4 rubber

Answer:

Option 1 is incorrect. Usually from olefins (alkenes) in conjunction with halides like chlorides say PVC (polyvinyl chloride). 2 is incorrect. This would have been correct if option C was not provided. **3 is correct**. The main use of nitrogen is to manufacture ammonia that is used extensively to make fertilizers. In addition, it is used to make explosives. 4 is incorrect, usually from olefins like isoprene (2-methyl-1,3-butadiene) monomers. Some are made from epoxy resins.

34. Gold and platinum group metals are found in nature in metallic form because

1 they are solids at room temperature

2 they are highly reactive

3 they are soluble in water

4 they are relatively inert

Answer:

Gold and platinum group metals are referred to as the noble metals and are not reactive to normal acids, bases, sulfur and oxygen at ambient conditions, hence option 4 is correct.

35. What transition metal is responsible for the color of topaz?

1 manganese

2 gold

3 **iron**

4 chromium

Answer:

Topaz is a yellow aluminium fluorosilicate gemstone contaminated with iron (Fe) that gives the characteristic color rendering option 3 correct.