NATIONAL SCIENCE OLYMPIAD CHEMISTRY EXAMINATION 2009

1. Which of the following statements is true of an electrolytic cell?

A. Oxidation occurs at the cathode
B. Reduction occurs at the anode
C. It converts chemical energy to electrical energy
D. None of the above

Answer: D

Regardless of whether an electrochemical cell is galvanic or electrolytic, oxidation takes place at the anode and reduction at the cathode. The easy way to remember this is to note that the first letters of each pair of words are matched, with vowel to vowel (**o**xidation-**a**node) and consonant to consonant (**r**eduction-**c**athode). In an electrolytic cell the application of an external voltage causes a non-spontaneous chemical reaction to occur.

Electrolysis is used extensively in metallurgical processes, such as in extraction (electrowinning) or purification (electrorefining) of metals from ores or compounds and in deposition of metals from solution (electroplating). Metallic sodium and chlorine gas are produced by the electrolysis of molten sodium chloride; electrolysis of an aqueous solution of sodium chloride yields sodium hydroxide and chlorine gas. Hydrogen and oxygen are produced by the electrolysis of water, i.e., electrolysis can split water into its constituent elements.

2. The oxidation number of chromium in the hypothetical polyatomic ion $Cr_7O_8^{2-}$ will be expected to be:

A. +14
B. +7
C. +2
D. -8

Answer: C

The total oxidation number for the seven Cr atoms and eight O atoms must be equal to -2, the charge on the ion. The oxidation number of non-elemental oxygen is -2 (except in peroxides). Thus:

$$(7)(x) + (8)(-2) = -2$$

Therefore, x = +2.

3. Two and a half grams (2.5 g) of calcium carbonate is sealed into a 250 cm^3 tube and heated to a constant temperature. The equation for the reaction is as follows:

$$CaCO_3 (s) \leftrightarrow CaO (s) + CO_2 (g) \quad \Delta H > 0$$

After equilibrium was reached 1.7 g of $CaCO_3$ remained. What is the value of the equilibrium constant K_C at this temperature?

A. 0.015
B. 0.001
C. 0.032
D. none of the above

Answer: C

Mass $CaCO_3$ used = 2.5 – 1.7 = 0.8 g

M $CaCO_3$ = 40 + 12 + (3x16) = 100 g

Amount of $CaCO_3$ used = 0.8 / 100 = 0.008 mol

From the equation amount of CO_2 formed = 0.008 mol

$[CO_2]$ = 0.008 / 0.25 = 0.032 $mol.dm^{-3}$

$K_C = [CO_2] = 0.032$

$CaCO_3$ and CaO are omitted from the K_C expression as they are both solids.

4. The concentration of CO_2 (g) in the equilibrium mixture in Question 3 above can be increased by:

A. adding more CaO (s)

B. adding more $CaCO_3$ (s)

C. increasing the pressure

D. increasing the temperature

Answer: D

Increasing the amount of a solid has no effect as it does not change its concentration. Increasing the pressure favours the reverse reaction as it leads to a decrease in the amount of gas. Increasing the temperature favours the forward reaction which is endothermic as it consumes heat.

5. An unstable nucleus is radioactive, which means that it spontaneously emits ionising radiation to become more stable. Four common types of such radiation are alpha particles, beta particles, positrons and gamma (γ) rays. Which of the following statements is true?

A. An alpha particle is identical to a helium nucleus

B. A positron is identical to a proton

C. Alpha particles penetrate farther in matter such as human tissue than beta particles

D. Gamma rays actually consist of equal numbers of alpha and beta particles

Answer: A

An alpha particle has a mass number of 4 (2 protons and 2 neutrons) and a charge of 2+, same as a helium nucleus. A beta particle is identical to an electron. A positron is similar to a beta particle except it has a charge of +1. Beta particles have less mass and move faster than alpha particles, thus they can penetrate farther into matter. Gamma rays are energy only, with very deep penetrating power.

Gamma-ray radiation has wavelengths that are generally shorter than a few tenths of an angstrom (10^{-10} metre) and gamma-ray photons have energies that are greater than tens of thousands of electron volts (eV). Gamma-ray photons, like their X-ray counterparts, are a form of ionizing radiation; when they pass through matter, they usually deposit their energy by liberating electrons from atoms and molecules. At the lower energy ranges, a gamma-ray photon is often completely absorbed by an atom and the gamma ray's energy transferred to a single ejected electron.

Medical applications of gamma rays include the valuable imaging technique of positron emission tomography (PET) and effective radiation therapy to treat cancerous tumours. Gamma rays cause significant biochemical changes in living cells and radiation therapies make use of this property to selectively destroy cancerous cells in small localized tumours. Radioactive isotopes are injected or implanted near the tumour; gamma rays that are continuously emitted by the radioactive nuclei bombard the affected area and arrest the development of the malignant cells.

6. Fission and fusion are nuclear reactions that both lead to the release of very large amounts of energy. The main difference between fission and fusion is:

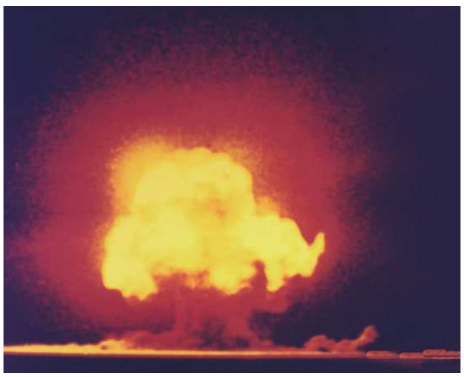
A. Fission is accompanied by a loss of mass which is converted into energy according to the well-known Einstein equation $E = mc^2$; there is no mass loss involved in fusion
B. Fusion produces far more energy that fission, but it requires extremely high temperatures to set it off.
C. The earth obtains most of its heat and light from fission reactions that occur continuously in the sun and stars
D. Fission involves the combination of small nuclei to form a larger nucleus, whereas fusion involves the splitting of a large nucleus.

Answer: B
Both fission and fusion involve the conversion of lost mass to energy. In the sun and stars a temperature of about 100 000 000 ºC is required to overcome the repulsion of the hydrogen nuclei and cause them to undergo fusion (not fission), releasing far more energy that is obtainable from fission. Fusion involves the combination of small nuclei (like H-1), whereas fission involves the splitting of relatively large nuclei (like U-235).

In nuclear fission the nucleus of an atom breaks up into two lighter nuclei. The process may take place spontaneously in some cases or may be induced by the excitation of the nucleus with a variety of particles (*e.g.,* neutrons, protons, deuterons, or alpha particles) or with electromagnetic radiation in the form of gamma rays. In the fission process, a large quantity of energy is released, radioactive products are formed, and several neutrons are emitted. These neutrons can induce fission in a nearby nucleus of fissionable material and release more neutrons that can repeat the sequence, causing a chain reaction in which a large number of nuclei undergo fission and an enormous amount of energy is released.

If controlled in a nuclear reactor, such a chain reaction can provide power for society's benefit. We, in South Africa, like several nations in the world, have a nuclear power plant doing exactly this, the Koeberg Power Station (picture from www.wikipedia.com) near Cape Town. Owned by Eskom, Koeberg is the only nuclear power plant on the African Continent.

If uncontrolled, as in the case of the so-called atomic bomb, a nuclear fission chain reaction can lead to an explosion of awesome destructive force as demonstrated during World War II in Nagasaki and Hiroshima.



The first atomic bomb test, near Alamogordo, N.M., July 16, 1945 (www.britannica.com).

7. Part of the carbon in a living plant is assimilated radioactive carbon-14 which is formed in the atmosphere by the activation of nitrogen by neutrons from cosmic rays. After death a plant stops assimilating carbon and the amount of carbon-14 starts to decrease with time due to beta decay of the carbon-14 to stable nitrogen-14. The half-life of carbon-14 is about 5 730 years. Given that a wooden roof beam recently discovered by archaeologists at the excavation site of an ancient Indian village in South America was found to contain one-eighth (1/8) of the amount of carbon-14 found in living plants, about how long ago was the village constructed?

A. 720 years
B. 45 840 years
C. 17 200 years
D. 22 900 years

Answer: C

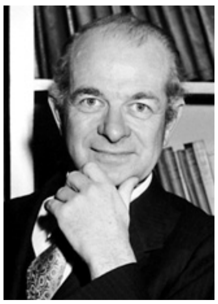
The half-life is the period it takes for the carbon-14 to reduce by decay to half of its initial amount. It follows that it will take three half-lives to reduce to one-eighth of the value when the tree was cut down for construction. Thus the age = 3 x 5 730 = 17 190 years.

8. The Nobel Prize in Chemistry has been awarded to 153 individuals since 1901, with Frederick Sanger being the only person to win it twice (in 1958 and 1980). The 2007 prize was awarded to:

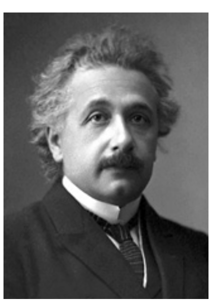
A. Linus Pauling
B. Gerhard Ertl
C. Albert Einstein
D. None of the above

Answer: B

Gerhard Ertl, (born 1936 in Germany, picture by the Nobel Foundation www.nobelprize.org) won the Chemistry award in 2007 for his studies of chemical processes on solid surfaces. Among his contributions, Professor Ertl deciphered all the steps in the reaction in which the nitrogen of the air is combined with hydrogen to form ammonia using surface catalysis (the Haber-Bosch Process). The question of the mechanism of this reaction had been a scientific enigma for decades. In addition, he clarified the subtle feedback mechanisms in the reaction occurring on the catalytic converters in the exhaust systems of our cars.



Linus Pauling (born 1901 in Postland, Oregon, died 1994; picture from www.nobelprize.org) won in 1954 for his studies into the nature of the chemical bond and its application to the elucidation of the structure of complex substances. In addition, he was awarded the Nobel Peace prize in 1962, because since the use of atomic bombs against Japan in 1946, "he campaigned ceaselessly, not only against nuclear weapons tests, not only against the spread of these armaments, not only against their very use, but against all warfare as a means of solving international conflicts."



Albert Einstein (born 1879, died 1955, www.nobelprize.org) received the Physics prize in 1921 "for his services to Theoretical Physics, and especially for his discovery of the law of the photoelectric effect." Einstein is generally considered the most influential physicist of the 20th century, credited with the theory of relativity.

9. VSEPR is the acronym for a theory used to predict molecular geometry (shape). It stands for:

A. Valence Shell Electron Pair Reaction
B. Valency Shell Electron Pair Repulsion
C. Valence Shell Electron Pair Repulsion
D. Valence Shell Electron Proton Reaction

Answer: C

The theory of molecular shape known as valence-shell electron-pair repulsion (VSEPR) theory grew out of Lewis' theory, and, like that approach to bonding, VSEPR focuses on the role of electron pairs. It stems from the work of the British chemists H.M. Powell and Nevil V. Sidgwick in the 1940s and was extensively developed by R.J. Gillespie in Canada and Ronald S. Nyholm in London during the 1960s. As such, it postdates quantum mechanical theories of bonding and shape but should be seen as an attempt to identify the essential features of a problem and to formulate them into a simple qualitative procedure for rationalization and prediction.

A Lewis dot structure is a topological portrayal of bonding in a molecule. It ascribes bonding influences to electron pairs that lie between atoms and acknowledges the existence of lone pairs of electrons that do not participate directly in the bonding. The VSEPR theory supposes that all electron pairs, both bonding pairs and lone pairs, repel each other—particularly if they are close—and that the molecular shape is such as to minimize these repulsions. The approach is commonly applied to species in which there is an identifiable central atom (the oxygen atom in H_2O, for instance), but it is straightforward to extend it to discussions of the local shape at any given atom in a polyatomic species. (www.britannica.com).

10. Applying VSEPR theory, a molecule in which there are three bonding domains but no lone pairs around the central atom is most likely to have ________ geometry.

A. trigonal planar
B. tetrahedral
C. linear
D. V-shaped

Answer: A

Linear if two bonding domains with no lone pairs around the central atom. V-shaped (or bent) if two lone pairs plus two bonding domains. Tetrahedral if four bonding domains with no lone pairs.

11. Which of the following statements is/are correct when atoms of two elements combine?

I. Atoms of the two elements are held together by electrostatic forces

II. The energy of the compound formed is lower than that of the separate atoms

III. Atoms of one element attain a more stable electron distribution whilst atoms of the other element attain a less stable electron distribution.

A. II only
B. I and II only
C. I, II and III
D. III only

Answer: B

I and II are both true. III is not true because all the atoms involved combine to obtain a more stable electron distribution.

12. An element A with three valence electrons combines with an element B with six valence electrons. The compound formed is most likely to be

A. covalent, with the formula A_3B_6
B. covalent, with the formula A_2B_3
C. ionic, with the formula A_2B_3
D. ionic, with the formula A_3B_2

Answer: C

A is likely a metal and it will lose the three valence electrons to form A^{3+} cation. B is likely a non-metal and it will gain two electrons to form B^{2-} anion. Electrostatic attraction will result in the formation of $[A^{3+}]_2[B^{2-}]_3$

13. The acid dissociation constant K_a value of hydrofluoric acid HF is 7×10^{-4}. A solution

is prepared by dissolving 0.1 mole of HF in 1 dm^3 of water. The dissociation equation is

$HF (aq) + H_2O (l) \leftrightarrow H_3O^+ (aq) + F^- (aq)$

Calculate the pH of the solution.

A. 4.2
B. 2.1
C. 8.02×10^{-3}
D. None of the above

Answer: B

	HF	H_2O	H_3O^+	F^-
Start	0.1 mol		0 mol	0 mol
Equilibrium	(01-x) mol		x mol	x mol
[Equilibrium]	(01-x) $mol.dm^{-3}$		X $mol.dm^{-3}$	x $mol.dm^{-3}$

The equilibrium constant

$K_a = [H_3O^+][F^-] / [HF]$

(water does not appear as it is a pure solvent)

$$7 \times 10^{-4} = x^2 / (0.1 – x)$$

Solve the quadratic equation (using the formula method) to obtain

$$x = 8.02 \times 10^{-3}$$

$$pH = -\log [8.02 \times 10^{-3}] = 2.1$$

Unlike hydrogen compounds of other halogens (HCl, HBr and HI) which are very strong acids with very large dissociation constants, hydrofluoric acid is a weak acid as evident from its dissociation constant. A qualitative explanation for this behaviour is related to the tendency of HF to hydrogen-bond and form ion-pair clusters such as $F^-\cdot H_3O^+$.

14. Whose atomic model established the idea of the atom as consisting of a small positively charged nucleus in which practically all the mass of the atom is concentrated, surrounded by negatively charged electrons in mostly empty space?

A. Dalton's
B. Thomson's
C. Rutherford's
D. Bohr's

Answer: C

Rutherford's model is the correct option.

Ernest Rutherford (born 1871 in Nelson, New Zealand, died 1937) was awarded the Nobel Prize in Chemistry in 1908 "for his investigations into the disintegration of the elements, and the chemistry of radioactive substances". Rutherford's discoveries led to the then highly surprising conclusion, "that a chemical element, in conflict with every theory hitherto advanced, is capable of being transformed into other elements, and thus in a certain way it may be said that the progress of investigation is bringing us back once more to the transmutation theory propounded and upheld by the alchemists of old" (www.nobelprize.org).

Dalton proposed a "billiard ball" model of a solid atom. Born September 5 or 6, 1766 in Eaglesfield, Cumberland, England, John Dalton John Dalton, an English meteorologist and chemist, was pioneer in the development of modern atomic theory.

Dalton's atomic theory earned him the sobriquet "father of chemistry." He died on July 27, 1844 in Manchester.

Thomson proposed a "currant bun" model of a sphere of a positively charged solid containing a uniform distribution of negatively charged electrons.

Sir Joseph John Thomson (born Dec. 18, 1856, Cheetham Hill, near Manchester, Eng. died Aug. 30, 1940, Cambridge) helped revolutionize the knowledge of atomic structure by his discovery of the electron (1897). He received the Nobel Prize for Physics in 1906 and was knighted in 1908.

Bohr introduced the idea of orbits in which electrons move around the nucleus, setting the stage for the modern "wave-mechanical" model. Niels Henrik David Bohr (born Oct. 7, 1885, Copenhagen, Denmark, died Nov. 18, 1962, Copenhagen) was the Danish physicist who is generally regarded as one of the foremost physicists of the 20th century. He was the first to apply the quantum concept, which restricts the energy of a system to certain discrete values, to the problem of atomic and molecular structure. For this work he received the Nobel Prize for Physics in 1922

Bohr's first contribution to the emerging new idea of quantum physics started in 1912 during what today would be called postdoctoral research in England with Ernest Rutherford at the University of Manchester. Only the year before, Rutherford and his collaborators had established experimentally that the atom consists of a heavy positively charged nucleus with substantially lighter negatively charged electrons circling around it at considerable distance. According to classical physics, such a system would be unstable, and Bohr postulated that electrons could only occupy particular orbits determined by the quantum of action and that electromagnetic radiation from an atom occurred only when an electron jumped to a lower-energy orbit. Although radical and unacceptable to most physicists at the time, the Bohr atomic model was able to account for an ever-increasing number of experimental data, famously starting with the spectral line series emitted by hydrogen (www.britannica.com).

15. In the chemical equation

$$H_2S + MnO_4^- \rightarrow Mn^{2+} + S + 2\ H^+$$

the substance that is oxidised is:

A. sulphur
B. the manganese ion
C. the permanganate ion
D. hydrogen sulphide

Answer: A

The oxidation number of sulphur increases from -2 in H_2S to 0 in S; increase in oxidation number indicates oxidation. Alternatively, $H_2S \rightarrow S + 2 H^+ + 2 e^-$; loss of electrons is oxidation.

16. The reaction between hydrogen sulphide and an acidified solution of iron(III) chloride can be represented by the following equation:

$H_2S + 2 FeCl_3 + HCl \leftrightarrow 2 FeCl_2 + S + 3 HCl$

The reduction half-reaction is represented by:

A. $H_2S \rightarrow S + 2 H^+ + 2 e^-$

B. $Fe^{3+} + e^- \rightarrow Fe^{2+}$

C. $Fe^{2+} \rightarrow Fe^{3+} + e^-$

D. $Fe^{3+} + 3 e^- \rightarrow Fe$

Answer: B

The Cl^- ions are spectator ions; their elimination simplifies the equation to

$H_2S + 2 Fe^{3+} \leftrightarrow 2 Fe^{2+} + S + 2 H^+$

This makes it easier to see that the reduction half-reaction is

$2 Fe^{3+} \rightarrow 2 Fe^{2+} + 2 e^-$ or $Fe^{3+} \rightarrow Fe^{2+} + e^-$

17. An electrochemical cell is constructed in order to supply electrical energy to a lamp. Which of the following unbalanced equations represents a cell reaction which can possibly meet this requirement?

A. $Cr_2O_7^{2-} + Mn^{2+} \rightarrow 2 Cr^{3+} + MnO_4^-$

B. $NO_3^- + SO_2 \rightarrow NO_2 + SO_4^{2-}$

C. $Ag + SO_4^{2-} \rightarrow Ag^+ + SO_2$

D. None of the above

Answer: B

To supply electrical energy the cell must operate as e a galvanic cell, therefore E_{cell} must be positive ($\Delta G = -nFE^o_{cell}$).

$$E_{cell} = E_{cathode} – E_{anode}.$$

A. $E^o_{cell} = E^o_{Cr2O72-/ Cr3+} – E^o_{MnO4-/ Mn2+} = 1.33 – (1.51) = -0.18$ V

B. $E^o_{cell} = E^o_{NO3-/NO2} – E^o_{SO42-/ SO2} = 0.80 – (0.17) = +0.63$ V

C. $E^o_{cell} = E^o_{SO42-/SO2} – E^o_{Ag+ /Ag} = 0.17 – (0.80) = -0.63$ V

18. For a certain reaction at equilibrium, the value of K_C at 200 ºC is 0.001. This means that

A. the reaction rate is very high

B. the reaction rate is very low

C. the reaction produces a low yield of products

D. the reaction produces a high yield of products

Answer: C

The low value of the equilibrium constant means that the ratio of the concentrations of products to concentrations of reactants is very low. No conclusions can be drawn about the reaction rate (how long it takes to attain equilibrium).

19. Huge quantities of fertilizer are produced annually in South Africa. This is applied to

the soil by farmers in order to increase the amount of plant nutrients in the soil. The most important nutrient element(s) required by plants is/are:

A. Nitrogen, Phosphorus and Potassium
B. Nitrogen, Phosphorus and Calcium
C. Nitrogen and Phosphorus only
D. Nitrogen only

Answer: A
Plants, as autotrophic organisms, use light energy to photosynthesize sugars from CO_2 and water. They also synthesize amino acids and vitamins from carbon fixed in photosynthesis and from inorganic elements garnered from the environment. Certain key elements are required, or essential, for the complex processes of metabolism to take place in plants. The required concentrations of each essential and beneficial element vary over a wide range.

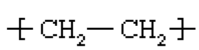
The essential elements required in relatively large quantities for adequate growth are called macroelements. Nine minerals make up this group: carbon (C), hydrogen (H), oxygen (O), nitrogen (N), potassium (K), calcium (Ca), magnesium (Mg), phosphorus (P), and sulfur (S). Seven other essential mineral elements are required in smaller amounts (0.01 percent or less) and are called microelements. These are iron (Fe), chlorine (Cl), manganese (Mn), boron (B), copper (Cu), molybdenum (Mo), and zinc (Zn). The specific required percentages may vary considerably with species, genotype (or variety), age of the plant, and environmental conditions of growth. A macronutrient is the actual chemical form or compound in which the macroelement enters the root system of a plant. The macronutrient source of the macroelement nitrogen, for example, is the nitrate ion (NO_3^-). Carbon dioxide from the atmosphere provides the carbon atoms and two-thirds of the oxygen required by plants. Water taken from the soil provides about one-third of the oxygen and much of the hydrogen. Soil provides macroelements and microelements from mineral complexes, parent rock, and decaying organisms.

Modern chemical fertilizers include one or more of the three elements that are most important in plant nutrition: nitrogen, phosphorus, and potassium. Of secondary importance are the elements sulfur, magnesium, and calcium. Nitrogen is an essential component of all proteins. Nitrogen deficiency most often results in stunted growth. Phosphorus is important in plant bioenergetics. As a component of ATP, phosphorus is needed for the conversion of light energy to chemical energy (ATP) during photosynthesis. Phosphorus can also be used to modify the activity of various enzymes by phosphorylation, and can be used for cell signalling. Since ATP can be used for the biosynthesis of many plant biomolecules, phosphorus is important for plant growth and flower/seed formation. Potassium regulates the opening and closing of the stoma by a potassium ion pump. Since stomata are important in water regulation, potassium reduces water loss from the leaves and increases drought tolerance. Potassium deficiency may cause necrosis or interveinal chlorosis.

20. The plastics industry in South Africa manufactures synthetic polymers by addition reactions of monomers. Which of the following plastic is correctly matched to its most common use?

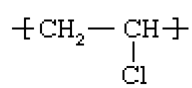
A. Polyethylene for plastic coffee cups
B. Polyvinyl chloride (PVC) for non-stick coatings
C. Polystyrene for plastic bottles
D. None of the above

Answer: D
Ethylene, commonly produced by the cracking of ethane gas, forms the basis for the largest single class of plastics, the polyethylenes. Ethylene monomer has the chemical composition CH_2=CH_2; as the repeating unit of polyethylene (PE) it has the following chemical structure:



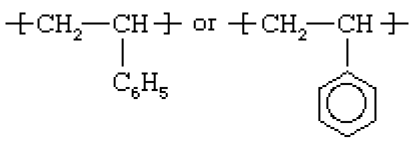
This simple structure can be produced in linear or branched forms. ranched versions are known as low-density polyethylene (LDPE) or linear low-density polyethylene (LLDPE); the linear versions are known as high-density polyethylene (HDPE) and ultrahigh molecular weight polyethylene (UHMWPE). LDPE is prepared from gaseous ethylene under very high pressures (up to 350 megaPascals) and high temperatures (up to 350° C). In the presence of peroxide initiators. These processes yield a polymer structure with both long and short branches. As a result, LDPE is only partly crystalline, yielding a material of high flexibility. Its principal uses are in packaging film, trash and grocery bags, agricultural mulch, wire and cable insulation, squeeze bottles, toys, and housewares.

Second only to PE in production and consumption, PVC is manufactured by bulk, solution, suspension, and emulsion polymerization of vinyl chloride monomer, using free-radical initiators. Vinyl chloride (CH_2=CHCl) is most often obtained by reacting ethylene with oxygen and hydrogen chloride over a copper catalyst. It is a carcinogenic gas that must be handled with special protective procedures. As a polymer repeating unit, its chemical structure is:

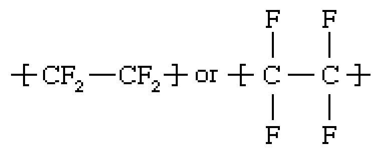


Pure PVC finds application in the construction trades, where its rigidity and low flammability are useful in pipe, conduit, siding, window frames, and door frames. In combination with plasticizer (sometimes in concentrations as high as 50 percent), it is familiar to consumers as floor tile, garden hose, imitation leather upholstery, and shower curtains.

Styrene, ($CH_2=CHC_6H_5$), also known as phenylethylene, is obtained by reacting ethylene with benzene in the presence of aluminum chloride to yield ethylbenzene, which is then dehydrogenated to yield clear, liquid styrene. The styrene monomer is polymerized using free-radical initiators primarily in bulk and suspension processes, although solution and emulsion methods are also employed. The structure of the polymer repeating unit can be represented as:



The presence of the pendant phenyl (C_6H_5) groups is key to the properties of polystyrene. These large, ring-shaped groups prevent the polymer chains from packing into close, crystalline arrangements, so that solid polystyrene is transparent. In addition, the phenyl rings restrict rotation of the chains around the carbon-carbon bonds, thus lending the polymer its noted rigidity. Foamed polystyrene is made into insulation, packaging, and food containers such as beverage cups, egg cartons, and disposable plates and trays. Solid polystyrene products include injection-moulded eating utensils, audiocassette holders, and cases for packaging compact discs. Many foods are packaged in clear, vacuum-formed polystyrene trays, owing to the high gas permeability and good water-vapour transmission of the material. Polytetrafluoroethylene (PTFE) is made from the gaseous monomer tetrafluoroethylene, ($CF_2=CF_2$) using high-pressure suspension or solution methods in the presence of free-radical initiators. The polymer is similar in structure to polyethylene, consisting of a carbon chain with two fluorine atoms bonded to each carbon:



The fluorine atoms surround the carbon chain like a sheath, giving a chemically inert and relatively dense product with very strong carbon-fluorine bonds. The polymer is inert to most chemicals, does not melt below 300° C (575° F), and has a very low coefficient of friction. These properties allow it to be used for bushings and bearings that require no lubricant, as liners for equipment used in the storage and transportation of strong acids and organic solvents, as electrical insulation under high-temperature conditions, and in its familiar application as a cooking surface that does not require the use of fats or oils.

21. There are four particularly important types of organic reactions, one of which is elimination reactions. The other three types are:

A. addition, substitution and rearrangement
B. addition, substitution and ring-formation
C. addition, rearrangement and ring-formation

D. addition, substitution and oxidation-reduction

Answer: A

An addition reaction is any of a class of chemical reactions in which an atom or group of atoms is added to a molecule. Addition reactions are typical of unsaturated organic compounds—*i.e.,* alkenes, which contain a carbon-to-carbon double bond, and alkynes, which have a carbon-to-carbon triple bond—and aldehydes and ketones, which have a carbon-to-oxygen double bond. An addition reaction may be visualized as a process by which the double or triple bonds are fully or partially broken in order to accommodate additional atoms or groups of atoms in the molecule. Addition reactions to alkenes and alkynes are sometimes called saturation reactions because the reaction causes the carbon atoms to become saturated with the maximum number of attached groups.

A substitution reaction is any of a class of chemical reactions in which an atom, ion, or group of atoms or ions in a molecule is replaced by another atom, ion, or group. An example is the reaction in which the chlorine atom in the chloromethane molecule is displaced by the hydroxide ion, forming methanol:

$$CH_3Cl + {}^{-}OH \rightarrow CH_3OH + Cl^{-}$$

If the chlorine atom is displaced by other groups—such as the cyanide ion (^{-}CN), the ethoxide ion ($C_2H_5O^{-}$), or the hydrosulfide ion (HS^{-})—chloromethane is transformed, respectively, to acetonitrile (CH_3CN), methyl ethyl ether ($CH_3OC_2H_5$), or methanethiol (CH_3SH). Thus an organic compound such as an alkyl halide can give rise to numerous types of organic compounds by substitution reactions with suitable reagents.

Rearrangement reactions are those in which a fragment breaks from one end of a molecule and reattaches itself at a different site on the same molecule, thereby giving a structural isomer of the molecule.

22. Fatty acids, proteins and enzymes are all organic macromolecules with important functions in the human body. Which of the following statements is/are true of the structure of these macromolecules?

I. A fatty acid contains a long hydrophobic carbon chain attached to a hydrophilic carboxylic acid group at one end

II. A protein consists of two amino acids linked by a peptide bond which is formed from the reaction of the $–COO^{-}$ group of one amino acid with the $–NH_3^{+}$ group of the other amino acid

III. Nearly all enzymes are globular proteins

A. II only

B. I and II only

C. I, II and III

D. I and III only

Answer: D

II is not accurate because it actually describes a dipeptide; a protein is a polypeptide containing more than 50 amino acids in a chain. Twenty different amino acids are common to proteins, linked in chains of hundreds to thousands of units. An active protein molecule has three important levels of structure: primary (the amino acid sequence, determined by the genes), secondary (the geometric shape, often a helix, determined by the angles of the covalent bonds between and within amino acids), and tertiary (the looped and folded overall shape, determined largely by attraction between oppositely charged groups and repulsion between like charged groups on amino-acid side chains and especially by hydrogen bonding).

The tertiary structure, which can be globular or sheetlike with ridges, crevices, or pockets, often holds the key to a protein's biological activity. Proteins can serve, e.g., as structural material (e.g., collagen in connective tissue and keratin in hair, nails), as enzymes and hormones (e.g., growth hormone), as transporters of essential substances such as oxygen (e.g., hemoglobin), as antibodies, or as regulators of gene expression. Some proteins are simple (amino acids only), some conjugated (to other groups, often vitamins or metal atoms atoms needed in tiny amounts in the diet.

Proteins may be covalently linked to other atoms or molecules, as to sugars (glycoproteins), phosphate groups (phosphoproteins), or sulfur (sulfoproteins).

Fatty acids are important components of lipids in plants, animals, and microorganisms. Generally, a fatty acid consists of a straight chain of an even number of carbon atoms, with hydrogen atoms along the length of the chain and at one end of the chain and a carboxyl group (−COOH) at the other end. It is this carboxyl group that makes it an acid. If the carbon-to-carbon bonds are all single, the acid is saturated; if any of the bonds is double or triple, the acid is unsaturated and is more reactive. A few fatty acids have branched chains; others contain ring structures (*e.g.,* prostaglandins). Fatty acids are not found in a free state in nature; commonly they exist in combination with the alcohol glycerol in the form of triglyceride.

The most widely distributed fatty acid is oleic acid ($CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$), which is abundant in some vegetable oils (*e.g.,* olive, palm, peanut, and sunflower seed). Many animals cannot synthesize one or more of the fatty acids and must ingest them in foods. Soaps are the sodium and potassium salts of fatty acids (www.britannica .com).

23. The types of bonds found within and between chemical species may be arranged in order of <u>increasing strength</u> as follows:

A. hydrogen; covalent, ionic; Van der Waals
B. Van der Waals, hydrogen; ionic; covalent
C. hydrogen; Van der Waals; ionic; covalent

D. covalent; ionic; hydrogen; Van der Waals

Answer: B

Van der Waal's forces and hydrogen bonds are relatively weak, intermolecular forces that hold molecules together and account for their observed bulk physical characteristics. Van der Waal's forces are all the electric forces that attract neutral molecules to one another in gases, in liquefied and solidified gases, and in almost all organic liquids and solids. The forces are named for the Dutch physicist Johannes van der Waals, who in 1873 first postulated these intermolecular forces in developing a theory to account for the properties of real gases. Solids that are held together by van der Waals forces characteristically have lower melting points and are softer than those held together by the stronger ionic, covalent, and metallic bonds.

A hydrogen bond is a stronger, more intermolecular interaction specific to molecules containing an oxygen, nitrogen, or fluorine atom that is attached to a hydrogen atom. It is an interaction of the form A−H⋯B, where A and B are atoms of any of the three elements mentioned above and the hydrogen atom lies on a straight line between the nuclei of A and B. A hydrogen bond is about 10 times as strong as the other interactions described above, and when present it dominates all other types of intermolecular interaction. It is responsible, for example, for the existence of water as a liquid at normal temperatures; because of its low molar mass, water would be expected to be a gas. The hydrogen bond is also responsible for the existence as solids of many organic molecules containing hydroxyl groups (−OH); the sugars glucose and sucrose are examples.

Ionic and covalent bonds are very strong intramolecular forces that hold atoms/ions within molecules together. In an ionic bond, the atoms are bound by attraction of opposite ions, whereas, in a covalent bond, atoms are bound by sharing electrons. In covalent bonding, the molecular geometry around each atom is determined by VSEPR rules, whereas, in ionic materials, the geometry follows maximum packing rules.

24. A compound consists of only the elements carbon, hydrogen, oxygen and nitrogen. Calculate its empirical (simplest) formula, given that it contains (by mass) 56.8 %C; 6.56 %H and 28.4 %O.

A. C_3H_4O
B. C_2H_3O
C. $C_8H_{11}O_3N$
D. The information provided is not enough to calculate the empirical formula

Answer: C

The empirical formula of a compound is a simple expression of the relative numbers of each type of atom in it, that is, the simplest whole number ratio of atoms of each element present in a compound. An empirical formula makes no reference to isomerism, structure, or absolute number of atoms. In contrast, the molecular formula identifies a numbers of each type of atom in a molecule, and the structural formula.

%N = 100 – (56.80 + 6.56 + 28.4) = 8.24

	C	H	O	N
No of moles	56.80 ÷12.0 = 4.73	6.56÷ 1.0 = 6.56	28.4÷ 16.0 = 1.78	8.24÷ 14 = 0.589
Mole ratio	4.73÷ 0.589 = 8.03	6.56÷ 0.589 = 11.1	1.78÷ 0.589 = 3.02	0.589÷ 0.589 = 1.0
	≈ 8	≈ 11	≈ 3	1

25. To analyse the alcohol content of a certain wine, a dietician needs 250 cm^3 of an aqueous 0.200 $mol.dm^{-3}$ $K_2Cr_2O_7$ solution. How much of solid $K_2Cr_2O_7$ must he weigh out to prepare this solution if the solid available to him is only 99.5 % pure?

A. 14.7 g
B. 14.8 g
C. 59.1 g
D. None of the above

Answer: B

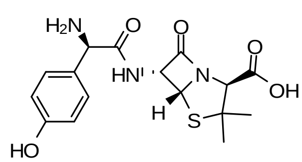
M_r $K_2Cr_2O_7$ = 2x39 + 2x52 + 7x16
= 294 $g.mol^-$
Mass = 0.200 $mol.dm^{-3}$ x 0.250 dm^3 x 294 $g.mol^-$ = 14.7 g pure solid
Mass = 14.7 g pure solid x 100 g impure solid/99.5 g pure solid = 14.8 g impure solid

26. The antibiotic AUGMENTIN® contains amoxycillin and potassium clavulanate. The purpose of the clavulanate is:

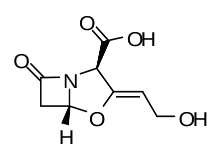
A. to act as a probiotic
B. to improve the flavour
C. to increase the solubility of the amoxycillin
D. to bind irreversibly to β-lactamases produced by bacteria

Answer: D

Amoxycillin and other penicillin antibiotics contain a β-lactam ring as part of their structure and this ring is essential for the antibiotic activity. Amoxicillin acts by inhibiting the synthesis of bacterial cell wall. It inhibits cross-linking between the linear peptidoglycan polymer chains that make up a major component of the cell walls of both Gram-positive and Gram-negative bacteria.



Amoxicillin


clavulanic acid

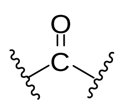
Certain bacteria produce β-lactamases and the bacteria use this enzyme to break the β-lactam ring of amoxycillin, making it ineffectual as an antibiotic. Clavulanic acid is a natural product that contains a β-lactam group, similar to that found in amoxycillin and other penicillins. When potassium clavulanate is present with amoxycillin (as in AUGMENTIN®) the bacterial β-lactamase reacts with the clavulanate and makes a stable enzyme complex (irreversible reaction) and this prevents the β-lactamases from being able to inactivate the amoxycillin, making sure that it maintains its effectiveness as an antibiotic.

27. Both of these compound types contain a carbonyl functional group:

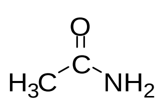
A. amide and ester
B. ester and alcohol
C. carboxylic acid and amine
D. alkyne and aldehyde

Answer: A

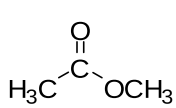
The carbonyl group may be represented as:



Any group may be attached to either side. For a compound to be an amide, however, the carbonyl group must be attached on one side to a nitrogen atom, for example:



For an ester, the carbonyl must be attached on one side to an oxygen atom that also carries an alkyl group, for example:



The other compounds listed that contain carbonyl groups are carboxylic acids and aldehydes. The compounds in the list that do not contain a carbonyl functional group are alcohols, amines and alkynes.

28. Which electronic configuration is most likely to give a stable +1 ion?

A. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$
B. $1s^2 2s^2 2p^6 3s^2 3p^5$
C. $1s^2 2s^2 2p^6 3s^2 3p^4$
D. none of the above

Answer: A

The electronic configuration for A has only one electron in the outer 4s orbital. Loss of this electron, to give a +1 ion, leads to an electronic configuration that is the same as that for a noble gas, with the outer shell full. This is a stable configuration and leads to a stable +1 ion. B and C need to gain electrons to fill their outer shells, and would thus form more stable -1 and -2 ions, respectively.

29. The gas liberated when an alkali metal reacts with water is:

A. O_2
B. H_2
C. H_2O vapour
D. A and B

Answer: B

The reaction of an alkali metal with water gives hydroxide and hydrogen gas. The reaction for Na serves as an example:

$$2Na\ (s) + 2H_2O(l) \rightarrow 2NaOH\ (aq.) + H_2(g)$$

30. Consider the reaction

$$2SO_2\ (g) + O_2\ (g) \rightleftharpoons 2SO_3\ (g)$$

Forward reaction ΔH = -198 kJ.

The effect of increasing the temperature will be:

A. to favour the forward reaction because of Boyle's Law
B. to favour the reverse reaction because of Boyle's Law
C. to favour the forward reaction because of Le Chatelier's Principle
D. to favour the reverse reaction because of Le Chatelier's Principle

Answer: D
Le Chatelier's Principle states that if the conditions (e.g., temperature, pressure or concentration) of an equilibrium system are changed, the reaction which tends to cancel the effect of the changes will be favoured. In the above example, heat is given off by the forward reaction (ΔH is negative) and thus when the temperature is increased, the equilibrium will shift in such a way as to decrease the temperature, thus favouring the reverse reaction which is endothermic.

Boyle's law states that the volume of a given mass of gas is inversely proportional to the pressure exerted on it, provided that the temperature remains constant. This is not applicable to the above situation.

31. The following reaction may be described as a fermentation reaction:

A. $HCl + NaOH \rightarrow H_2O + NaCl$
B. $C_6H_{12}O_6 \rightarrow CH_3COCOOH \rightarrow CH_3CH_2OH$
C. $CH_3CH_2OH \rightarrow CH_3CHO \rightarrow CH_3COOH$
D. none of the above

Answer: B
Reaction B shows the conversion of glucose to pyruvic acid and subsequent formation of ethanol. Fermentation is the process of deriving energy from organic compounds, such as carbohydrates where organic compounds act as both donors and acceptors of electrons. Fermentations can be carried out in the presence or absence of oxygen. Some organisms such as yeast cells greatly prefer fermentation to other methods of energy generation, as long as sugars are readily available for consumption. Sugars are the most common substrate of fermentation, and typical examples of fermentation products are ethanol, lactic acid, and hydrogen. This reaction is exploited by man for brewing of beer, for example.

32. $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

In the above reaction:

A. NH_3 is the acid and OH^- the conjugate base
B. H_2O is the acid and OH^- the conjugate base
C. NH_3 is the base and NH_4^+ the conjugate base
D. H_2O is the base and NH_4^+ the conjugate acid

Answer: B

In this reaction, H_2O is acting as the acid, as it is donating a proton to become OH^- , OH^- is thus the conjugate base. H_2O is a weak acid and OH^- a strong base, making up the acid-base pair. For an acid-base pair, if the acid is weak, the conjugate base is strong and vice versa.

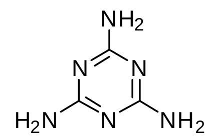
33. Detergents typically possess a non-polar hydrocarbon "tail" and a polar head. The length of the non-polar hydrocarbon is typically:

A. C_4-C_6
B. C_{30}-C_{35}
C. C_{12}-C_{18}
D. C_8-C_{10}

Answer: C

Detergents can be used to remove grease from surfaces or materials using water because the long tail of the detergent is nonpolar and hydrophobic ("water-fearing") and associates with the grease, while the polar head of the detergent faces towards the polar water molecules. This allows the grease to be broken up into small microdroplets, as the polar head of the detergent interacting with the water molecules prevents the unfavourable interaction between the nonpolar grease and the polar water molecules. It has been found that chain lengths for the hydrophobic tail of between 12 and 18 carbons work most efficiently for this purpose.

34. Baby milk formula from China was recently responsible for many infants becoming ill. This milk formula was found to contain melamine, below, which can be described as:



A. a triazine
B. a heterocyclic compound
C. a means of artificially enhancing the apparent protein content of the milk formula
D. All of the above

Answer: D

Melamine is a triazine (triaza = three nitrogens) and it is a heterocyclic compound (a ring compound containing at least one non-carbon atom as part of the ring). Melamine was deliberately and illegally added to the baby milk formula to increase the apparent protein content of the milk, as the test that is used for proteins actually tests for the percentage of nitrogen present. This happened in China, creating a great scandal in that country in 2008, leading to the arrest and execution of some people and resulted in a global dairy products scare that was reported in the media worldwide. Because melamine contains a large number of nitrogen atoms, it increases the percentage nitrogen content of the milk formula, giving a higher apparent protein content.

35. Laboratory glassware (e.g., Pyrex) is made of borosilicate glass. This glass is prepared by adding the following compounds to silica sand:

A. Na_2CO_3 and $NaHCO_3$
B. B_2O_3 and Al_2O_3
C. $ZnSO_4$ and $CuSO_4$
D. $AgNO_3$ and $Ca(NO_3)_2$

Answer: B
In making normal glass, sodium carbonate, together with some calcium carbonate, are added to silica sand. This glass is used to make containers such beer bottles, mayonnaise jars, bowls, vases, etc. One of the problems with normal glass is that it expands when heated and then contracts unevenly as it cools down. This means that stress points are formed and the glass is prone to shattering. If most of the sodium carbonate is replaced by boron oxide (B_2O_3) and some of the calcium carbonate is replaced by aluminium oxide (Al_2O_3) the resulting glass is thermally stable and can be used for making laboratory glassware, (for example beakers, test-tubes, reaction flasks, etc,) as the glass is not prone to shattering when heated and cooled repeatedly.

36. The reactions responsible for the colour and flavour of toasted bread and roasted meat are collectively known as:

A. Aldol reactions
B. Maillard reactions
C. Einstein reactions
D. Esterification reactions

Answer: B
The Maillard reactions are reactions that occur between amino acids and reducing sugars when heat is applied. This will occur, for example, between the amino acids and sugars present in bread when the bread is heated during the toasting process. Many different compounds are formed in these reactions and the combination of all these products gives toasted and roasted food interesting odours and flavours.

37. The following reaction scheme shows the neutralization reaction of oxalic acid with sodium hydroxide:

$$C_2H_4O_4 + 2NaOH \rightarrow C_2O_4Na_2 + 2H_2O$$

If it takes 35 ml of an oxalic acid solution of concentration 0.21 $mol.l^{-1}$ to neutralize 20 ml of a sodium hydroxide solution, what is the concentration of the sodium hydroxide solution?

A. 0.10 $mol.l^{-1}$
B. 0.369 $mol.l^{-1}$
C. 0.735 $mol.l^{-1}$
D. 0.210 $mol.l^{-1}$

Answer: C
First calculate the number of moles of oxalic acid needed for the neutralization:
$n = cV$
$n = 0.21\ mol.l^{-1} \times 0.035\ l = 0.00735$ moles

According to the neutralization equation, for every mole of oxalic acid, there must be two moles of NaOH

Therefore, 2 x 0.00735 moles = 0.0147 moles NaOH

This number of moles is present in a volume of 20 ml, therefore to calculate [NaOH]

c = n/V

c = 0.0147 mole/0.02 l = 0.735 $mol.l^{-1}$

38. Plaster of Paris that is used for setting of broken bones is prepared from gypsum. The reaction may be represented as:

A. $CaO + H_2O \rightarrow Ca(OH)_2$

B. $2CaSO_4 \bullet 2H_2O \rightarrow (CaSO_4)_2 \bullet H_2O + 3H_2O$

C. $2Al + 3CuSO_4 \rightarrow Al_2(SO_4)_3 + 3Cu$

D. $Fe_2O_3 + 3H_2O \rightarrow 2Fe(OH)_3$

Answer: B

Gypsum is a hydrate of calcium sulphate. Plaster of Paris is prepared by heating this hydrate so that it loses some of its water of hydration. For each two units of $CaSO_4$, it loses three of the four water molecules. This partially dehydrated form of gypsum (plaster of Paris) is used as a fine powder, which on addition of water to form a paste hardens within a few minutes. The solidification of moist plaster of Paris is a chemical reaction in which calcium sulphate absorbs water to give gypsum, the reverse reaction to that shown above.

39. Phosphorus and oxygen react to produce phosphorus oxide:

$P_4 + 5O_2 \rightarrow 2P_2O_5$

How many moles of oxygen need to react to produce 0.38 mol of P_2O_5?

A. 0.95

B. 0.38

C. 0.19

D. 1.90

Answer: A

From the equation, 5 moles of oxygen react to give 2 moles of phosphorus oxide. Using ratio and proportion:

5 mol $\rightarrow$ 2 mol

x mol $\rightarrow$ 0.38 mol

$2x = 5 \times 0.38$

$x = 5 \times 0.38/2 = 0.95$ moles

40. Aluminium is one of the most important structural metals used today. Aluminium is produced:

A. by electrolysis of aluminium oxide in molten cryolite

B. directly from mining seams of Al metal

C. as a by-product in the smelting of iron ore

D. none of the above

Answer: A

The electrolysis of aluminium is known as the Hall-Héroult process. The method was developed independently by Charles Hall and Paul Héroult in 1886. Aluminium is highly reactive and therefore ordinary methods for extracting metals from ores don’t work. Early attempts at electrolysis failed because aluminium oxide has a very high melting point (>2000ºC). Hall and Héroult discovered that aluminium oxide dissolves in a mineral called cryolite (Na_3AlF_6) to give a conducting mixture with a lower melting point. This can be used for electrolysis to produce aluminium metal.

41. There are _____ electrons, ______ protons and _______ neutrons in an atom of

$$^{235}_{92}U$$

A. 143, 143, 235
B. 92, 92, 235
C. 92, 92, 143
D. 143, 143, 92

Answer: C

The mass number (above and to the left of the element symbol) shown is 235. The mass number is equal to the number of protons plus the number of neutrons. The atomic number (below and to the left of the element symbol) given is 92. The atomic number is equal to the number of protons. Thus the number of neutrons is equal to the mass number minus the atomic number:

235 – 92 = 143

In a neutral atom the number of protons is equal to the number of electrons, therefore there are 92 electrons.

42. Which important technique used by Rosalind Franklin and Maurice Wilkins contributed significantly to the determination of the structure of DNA?

A. mass spectrometry
B. DNA fingerprinting
C. X-ray diffraction
D. polymerase chain reaction (PCR)

Answer: C

X-ray diffraction is extremely useful for studying the structures of large molecules. Franklin and Wilkins performed x-ray diffraction experiments on DNA fibres and obtained x-ray diffraction photographs. This information assisted James Watson and Francis Crick to come to the conclusion that DNA possesses a double helix structure. Information about the geometry or shape of molecules can be obtained using x-ray diffraction by looking at the scattering pattern that results from the molecules being subjected to x-rays.

43. Free radical chemistry has many important applications, including in the plastics industry. Radical chain reactions involve the following steps:

A. initiation, propagation and termination
B. initiation, branching and acidification
C. propagation, hydrolysis and termination
D. none of the above

Answer: A

A free radical chain reaction begins with an initiation step where the free radicals are produced. The chain continues with one or more propagation steps, where product plus another free radical are produced. There may also be branching steps involved. The reactions that remove free radicals from the system are called chain termination steps.

44. In the following example what does the vertical arrow represent?

$CuSO_4 + CaCl_2 \rightarrow CuCl_2 + CaSO_4\downarrow$

A. this is the compound that lowers the pH of the solution
B. this means the reaction is endothermic
C. this compound precipitates out of solution
D. less of this compound is formed than of the other product

Answer: C
The vertical arrow pointing down has only one meaning and this is that the compound forms a precipitate.

45. Which of the statements is true and correctly completes the following:

Attempting to exercise at high altitude (>3000 m) without prior acclimatization can be dangerous because

A. the higher level of oxygen at higher altitudes leads to dizziness and fainting
B. the blood has a reduced ability to take up oxygen and the result is over-breathing that leads to an increase in blood pH
C. the blood has a reduced ability to take up oxygen and the result is over-breathing that leads to a decrease in blood pH
D. the high levels of ozone carry health risks

Answer: B
The partial pressure of oxygen is lower at high altitude than at sea-level. This results in the blood having a reduced ability to take up oxygen. To compensate for this, the breathing rate increases. Over-breathing at high altitude causes a loss of CO_2. This effectively means a loss of acid from the body (CO_2 in the blood acts as an acid by neutralizing excess OH^- and forming HCO_3^-). This loss of acid means the basicity increases and can cause an increase in blood pH, which can be dangerous.

46. Calculate the percentage by mass of beryllium in the mineral beryl:

$Be_3Al_2(SiO_3)_6$

A. 5.0%
B. 11.3%
C. 0.05%
D. 25.0%

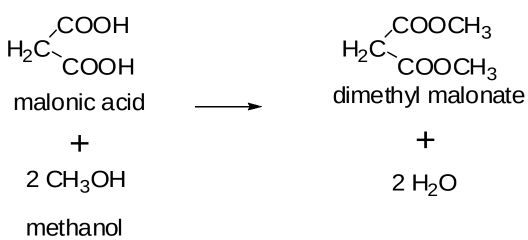
Answer: A
Use the periodic table to find the molar masses of the elements. The percentage beryllium is calculated as follow:

$$\frac{(9.01 \text{ x } 3) \text{ x } 100}{(9.01 \text{ x } 3) + (26.98 \text{ x } 2) + (28.086 \text{ x } 6) + (16 \text{ x } 3 \text{ x } 6)}$$

= 5.03%
Beryl is a commercial source of the element berylium. It has long been of interest because several varieties are valued as gemstones. These are aquamarine (pale

blue-green); emerald (deep green); heliodor (golden yellow); and morganite (pink). Beryl is a minor constituent of many granitic rocks and associated pegmatite dikes, in gneisses, and in mica schists. The gem varieties (other than emerald) commonly are found in cavities in pegmatites. Emeralds occur in mica schist and in bituminous limestone. Common beryl of nongem quality is present in many pegmatites, usually disseminated in small crystals.

47. What is the maximum mass of dimethyl malonate that can be prepared from 10.0 g of malonic acid and 4.0 g of methanol in the reaction shown below?



A. 12.7 g
B. 8.3 g
C. 14.0 g
D. 16.5 g

Answer: B

First the molar masses of malonic acid, methanol and dimethyl malonate need to be calculated:

Malonic acid ($C_3H_4O_4$): (3 x 12.01) + (4 x 1.01) + (4 x 16) = 104.07

Methanol (CH_4O): (1 x 12.01) + (4 x 1.01) + (1 x 16) = 32.05

Dimethyl malonate ($C_5H_8O_4$): (5 x 12.01) + (8 x 1.01) + (4 x 16) = 132.13

Now calculate how many moles of malonic acid and methanol you are starting with:

Malonic acid: 10 g

n = m/MW = 10/104.07 = 0.0961 mol

Methanol: 4 g

n = m/MW = 4/32.05 = 0.125 mol

Now we must decide which of the two reagents is the limiting reagent. For every one mole of malonic acid we need 2 moles of methanol. But we do not have twice as many moles of methanol as malonic acid, we only have 0.125/0.0961 = 1.3 x the amount. This means that methanol is the limiting reagent. Therefore, we can only react 0.125/2 = 0.0625 moles of malonic acid. If we can only react 0.0625 moles of malonic acid then we can only make 0.0625 moles of dimethyl malonate.

Now we must calculate how much 0.0625 moles of dimethyl malonate weighs:

mass = n x MW = 0.0625 x 132.13 = 8.26 g

48. In the following reaction

$NH_4Cl + NaOH \rightleftharpoons NH_3 + H_2O + NaCl$

Cl^- and Na^+ are called:

A. conjugate acids
B. conjugate bases
C. rate-limiting reagents
D. spectator ions

Answer: D

The reaction is actually taking place between NH_4^+ and OH^-, the Cl^- and Na^+ are not involved in the reaction and are therefore called spectator ions.

49. Groundwater from certain areas forms scum when lathered with soap. This so-called “hard water” contains ions that form precipitates with ordinary soap. Examples of these ions are:

A. Ca^{2+}, Mg^{2+}
B. Na^+, K^+
C. F^-, Cl^-
D. Pb^{2+}, Ni^{2+}

Answer: A

Ions such as Ca^{2+}, Mg^{2+}, Fe^{2+} and Fe^{3+} form insoluble “scum” with the hydrophobic tails of ordinary soaps. This makes the soaps ineffective. These ions can be removed from water by a number of methods, one of which is to precipitate these ions as carbonates, by addition of sodium carbonate to the water.

50. Alkynes are compounds that contain:

A. a conjugated double bond
B. a triple bond
C. a halide ion
D. none of the above

Answer: B

Alkynes are compounds that contain triple bonds, an example, 2-butyne, is shown below:

$$H_3C-C\equiv C-CH_3$$

The triple bond is very strong with a bond strength of 839 kJ/mol. Because they are unsaturated, alkynes undergo addition reactions and are more reactive that their alkene counterparts (compounds with carbon-carbon double bonds). Like alkenes, alkynes can also be polymerized to long chains of carbon atoms with alternating single and double between them, each with one hydrogen atom. Called polyacetylenes, possess high electrical conductivity and when doped with iodine, polyacetylene has conductivity that approaches the conductivity of the best available conductor, silver. Alan J. Heeger, Alan G. MacDiarmid and Hideki Shirakawa were awarded the 2000 Nobel Prize in chemistry for the discovery and development of conductive polymers.

Alkynes occur in to a limited extent in nature. Molecules called ene-diynes feature a ring containing an alkene ("ene") between two alkyne groups ("diyne"). These compounds such as calicheamicin (from bacteria *Mircromonospora echinospora*) and esperamicin are the two most potent antitumor agents known.