BioMedical Admissions Test (BMAT)

Section 2: Chemistry

Knowledge Checklist (2021-2022)

CHEMISTRY

C1. Atomic structure

C1.1 Describe the structure of the atom as a central nucleus (containing protons and neutrons) surrounded by electrons moving in shells/energy levels.

C1.2 Know the relative masses and charges of protons, neutrons and electrons, and recognise that most of the mass of an atom is in the nucleus.

C1.3 Know and be able to use the terms *atomic number* and *mass number*, together with standard notation (e.g. $^{12}_{6}C$), and so be able to calculate the number of protons, neutrons and electrons in any atom or ion.

C1.4 Use the atomic number to write the electron configurations of the first 20 elements in the Periodic Table (H to Ca) in comma-separated format (e.g. 2,8,8,1 for a potassium atom).

C1.5 Know the definition of isotopes as atoms of an element with the same number of protons but different numbers of neutrons (so having different mass numbers). Use data, including that from a mass spectrometer, to identify the number and abundances of different isotopes of elements.

C1.6 Know and use the concept of relative atomic mass, A_r, including calculating values from given data.

C2. The Periodic Table (IUPAC conventions, Groups are labelled as 1-18)

C2.1 Know that Periods are horizontal rows and Groups are vertical columns.

C2.2 Know that the elements are arranged in the order of increasing atomic number.

C2.3 Recall the position of metals and non-metals in the Periodic Table: alkali metals (Group 1), alkaline earth metals (Group 2), common non-metals in Group 16, the halogens (Group 17), the noble gases (Group 18) and the transition metals.

C2.4 Know and use the relationship between the position of an atom in the Periodic Table (Group and Period) and the electron configuration of the atom.

C2.5 Understand that elements in the same Group have similar chemical properties and that down a metal Group, reactivity increases and down a non-metal Group, reactivity decreases.

C3. Chemical reactions, formulae and equations

C3.1 Understand that in a chemical reaction, new substances are formed by the rearrangement of atoms and their electrons, but no nuclei are destroyed or created.

C3.2 Know the chemical formulae of simple, common ionic and covalent compounds.

C3.3 Know and use state symbols: solid (s), liquid (l), gas (g), aqueous solution (aq).

C3.4 Be able to construct and balance a chemical equation, including ionic and half-equations.

C3.5 Understand that often chemical reactions can be reversible and do not go to completion. All of the reactants do not turn fully into the products but the reaction reaches a state of equilibrium in a closed system.

a. Know the factors that can affect the position of an equilibrium (concentration of reactants/products, temperature, overall pressure).

b. Predict the effect of changing these factors on the position of equilibrium.

C4. Quantitative chemistry

C4.1 Use A_r values to calculate the relative molar mass, M_r.

C4.2 Know that Avogadro's number gives the number of particles in one mole of a substance.

C4.3 Know that one mole of a substance is the A_r or M_r in grams, and perform conversions of grams to moles and *vice versa* (including working in tonnes and kilograms). Know that the amount of a substance corresponds to the number of moles of a substance.

C4.4 Calculate the percentage composition by mass of a compound using given A_r values.

C4.5 Know that the *empirical formula* is the simplest integer ratio of atoms in a compound. Find the empirical formula of a compound from a variety of data, such as the percentage composition by mass of the elements present or reacting masses. Find the molecular formula from the empirical formula if given the M_r value.

C4.6 Use balanced chemical equations to calculate the masses of reactants and products, including if there is a limiting reactant present.

C4.7 Be able to construct balanced chemical equations from reacting masses or gas volumes data.

C4.8 Understand that (for an ideal gas) one mole of a gas occupies a set volume at a given temperature and pressure (for example, 24 dm^3 at room temperature and pressure (rtp)), and perform conversions of volumes to number of moles, and *vice versa*.

C4.9 Solutions:

a. Understand that concentration can be measured in mol dm^{-3} or g dm^{-3}, and be able to calculate the concentration given the number of moles (or mass) of solute and the volume of solution.

b. Know the term *saturated solution*, be able to calculate solubility and interpret solubility data.

C4.10 Use the concentrations of solutions (or find the concentrations from given data) and the reacting ratio of reactants from the balanced equation to perform titration calculations.

C4.11 Calculate the percentage yield of a reaction using the balanced chemical equation and the equation: $\text{percentage yield} = \frac{\text{actual yield (g)}}{\text{predicted yield (g)}} \times 100$

C5. Oxidation, reduction and redox

C5.1 Know that on a basic level, oxidation is the gain of oxygen and that reduction is the removal of oxygen.

C5.2 Know and be able to use the concept that oxidation and reduction are the transfer of electrons, i.e. reduction is the gain of electrons and oxidation is the loss of electrons.

C5.3 Determine and use the oxidation states of atoms in simple inorganic compounds.

C5.4 Identify any chemical equation that involves: oxidation only, reduction only, redox (both oxidation and reduction taking place), or no oxidation/reduction.

C5.5 Understand the concept of *disproportionation* and recognise reactions (or species) where this occurs.

C5.6 Understand the terms *oxidising agent* and *reducing agent*, and be able to identify them in reactions.

C6. Chemical bonding, structure and properties

C6.1 Define and understand the differences between elements, compounds and mixtures.

C6.2 Understand that atoms often react to form compounds which have the electron configuration of a noble gas (Group 18). Understand that the type of bonding taking place depends on the atoms involved in the reaction.

C6.3 Ionic bonding:

a. Know that ions are formed by transfer of electrons from atoms of metals to atoms of non-metals, and that these ions (of opposite charge) attract to form ionic compounds.

b. Predict the charge of the most stable ions formed from elements in Groups 1, 2, 16 and 17 and aluminium by consideration of their electron configuration.

c. Know the chemical formulae of common compound ions, e.g. CO_3^{2-} and OH^-.

d. Know that when an element can exist in more than one oxidation state, e.g. Cu, Fe, then Roman numerals are used to denote the one present, e.g. iron(III) chloride for $FeCl_3$.

e. Determine the formulae of ionic compounds from their constituent ions.

f. Understand the general physical properties of ionic compounds, such as melting point and conductivity.

C6.4 Covalent bonding:

a. Know that a covalent bond is formed when atoms share one (or more) pair(s) of electrons, generally between non-metals.

b. Understand that covalently bonded substances can be small molecules (e.g. water, ammonia, methane) or giant structures (e.g. diamond, graphite, silicon dioxide).

c. Understand the general physical properties of substances composed of small molecules or of those that exist as giant covalent structures.

C6.5 Metallic bonding:

a. Understand that solid metals exist as a giant structure of positively charged ions surrounded by delocalised (free) electrons.

b. Understand the general physical properties of metals, such as melting point and conductivity.

C6.6 Understand that intermolecular forces can exist between molecules, and that these forces must be overcome in melting and boiling.

C6.7 Be able to relate structure and bonding to physical properties, such as melting point and conductivity.

C7. Group chemistry

C7.1 Know the physical and chemical properties of the alkali metals (Group 1), the halogens (Group 17) and the noble gases (Group 18).

C7.2 Describe the trends in chemical reactivity and physical properties of the alkali metals (Group 1) and make predictions based on those trends.

C7.3 The halogens (Group 17):

a. Describe the trends in chemical reactivity and physical properties of the halogens and make predictions based on those trends.

b. Explain what is meant by a displacement reaction, in terms of reactivity competition, between halogens and halide ions.

C8. Separation techniques

C8.1 Know that chemical processes are required to displace constituent elements from their compounds.

C8.2 Know that physical processes are required to separate mixtures, including miscible/immiscible liquids and dissolved/insoluble solids.

C8.3 Know when to apply the following separation techniques: simple/fractional distillation, paper chromatography (including use of R_f values), use of a separating funnel, centrifugation, dissolving, filtration, evaporation and crystallisation.

C8.4 Know how to establish the purity of a substance using chromatography.

C9. Acids, bases and salts

C9.1 Acids:

a. Define an acid as a substance that can form $H^+(aq)$ ions or that is an H^+ donor.

b. Describe reactions with metals, carbonates, metal hydroxides and metal oxides in which salts are formed.

c. Understand the terms *strong*, *weak*, *dilute* and *concentrated*.

d. Know that some oxides of non-metals react with water to form acidic solutions.

e. Recall that pH is a measure of H^+ ion concentration, and recall that a change of 1 on the pH scale corresponds to a change by a factor of 10 in H^+ ion concentration.

f. Know that one mole of some acidic substances is able to form/donate more than one mole of H^+ ions, including the use of the terms *mono-*, *di-*, *tri-*, and *polyprotic*.

C9.2 Bases:

a. Define a base as a substance that can form $OH^-(aq)$ ions or that is an H^+ acceptor.

b. Understand the terms *strong*, *weak*, *dilute* and *concentrated*.

c. Know that some oxides and hydroxides of metals react with water to form alkaline solutions.

C9.3 Know that the reaction of an acid with a base can lead to neutralisation and is often exothermic.

C10. Rates of reaction

C10.1 Describe the qualitative effects on a rate of reaction of concentration, temperature, particle size, a catalyst and, for gases, pressure.

C10.2 Know that the rate of reaction can be found by measuring the loss of a reactant or the gain of a product, or by measurement of a physical property over time, and be able to identify which of these measurements can be used in a given situation.

C10.3 Interpret data in graphical form concerning the rate of a reaction.

C10.4 Use collision theory to explain changes in the rate of a reaction.

C10.5 Understand that particles must have sufficient energy when they collide to react, and that this energy is called the activation energy (E_a). Identify the activation energy on an energy level diagram.

C10.6 Know that catalysts:

a. are not used up in a reaction.

b. are chemically unchanged at the end of a reaction.

c. provide an alternative route (reaction mechanism) with a lower activation energy, and interpret this effect on an energy level diagram.

d. do not affect the position of an equilibrium.

C11. Energetics

C11.1 Understand the concepts of an exothermic reaction, for which ΔH is negative (negative enthalpy change), and an endothermic reaction, for which ΔH is positive (positive enthalpy change).

C11.2 Know that if a reversible reaction is exothermic in one direction, it is endothermic in the other direction.

C11.3 Be able to interpret energy level diagrams.

C11.4 Be able to calculate energy changes from specific heat capacities and changes in temperature in calorimetry experiments.

C11.5 Know that bond breaking is endothermic and bond formation is exothermic, and be able to use bond energy data to calculate energy changes.

C12. Electrolysis

C12.1 Understand the terms *electrode*, *cathode (negative electrode)*, *anode (positive electrode)* and *electrolyte*.

C12.2 Understand why direct current (dc), and not alternating current (ac), is used in electrolysis.

C12.3 Understand that in electrolysis at the cathode, the cations (positively charged ions) receive electrons (reduction) to change into atoms or molecules, and at the anode, the anions (negatively charged ions) lose electrons to form atoms or molecules (oxidation).

C12.4 Understand and be able to predict the products of the electrolysis of the following:

a. aqueous solutions (including those of salts), including situations where more than one ion/molecule is attracted to a single electrode

b. molten binary compounds

C12.5 Be able to write half-equations for the processes taking place at each electrode.

C12.6 Explain how electrolysis is used to electroplate objects.

C13. Carbon/Organic chemistry

C13.1 General concepts:

a. Know that crude oil is the main source of hydrocarbons and that it is separated into fractions by fractional distillation (names and uses of specific fractions not expected).

b. Understand the link between carbon chain length and the following trends in physical properties of hydrocarbons: boiling points, viscosity, flammability.

c. Know the use of longer chain alkanes in cracking to form shorter chain alkanes and alkenes, and be able to write balanced chemical equations for these reactions.

d. Understand structural isomerism and be able to recognise examples.

e. Understand and be able to use the following terms: *molecular formula, full structural formula (displayed structure)* and *condensed structural formula*.

f. Understand and be able to use the terms *complete combustion* and *incomplete combustion*, and be able to write balanced chemical equations for such reactions.

g. Know the IUPAC guidelines for the systematic naming of carbon compounds, and apply the guidelines in order to be able to name all the compounds in this section of the specification.

h. Know and understand the terms *homologous series* and *functional group*.

C13.2 Alkanes (saturated hydrocarbons):

a. Describe alkanes as a homologous series with the general formula of C_nH_{2n+2}.

b. Be able to name, or recognise from the name, the C1 to C6 straight-chain alkanes.

C13.3 Alkenes (unsaturated hydrocarbons):

a. Describe alkenes as a homologous series with a double bond and the general formula C_nH_{2n}.

b. Be able to name, or recognise from the name, C2 to C6 straight-chain alkenes, including the position of the double bond.

c. Recognise and be able to use the test for unsaturation with bromine water.

d. Know that addition reactions take place with the following substances: hydrogen, halogens, hydrogen halides and steam. Be able to write the balanced chemical equations for these reactions and recognise the formulae of the products formed. (Mechanisms and consideration of carbocation stability are **not** required.)

C13.4 Polymers:

a. Addition polymerisation, polyalkenes:

i. Know that alkenes or other molecules with a C=C bond may react with each other to form long-chain saturated molecules called polymers by addition reactions called polymerisation, and that the unsaturated molecules are called monomers.

ii. If given an unsaturated monomer molecule, be able to recognise the structure of the polymer and *vice versa*.

iii. Be able to recognise the repeating unit of these polymers.

b. Condensation polymerisation, polyesters and polyamides (to include amino acids forming proteins):

   i. If given the monomer molecules, be able to recognise the structure of the polymer and *vice versa*.

   ii. Be able to recognise the repeating unit of these polymers.

c. Understand the terms *biodegradable* and *non-biodegradable* when applied to polymers.

C13.5 Alcohols:

a. Describe alcohols as a homologous series with the general formula $C_nH_{2n+1}OH$.

b. Be able to name, or recognise from the name, C1 to C6 straight-chain alcohols, including the position of the -OH group.

c. Describe the reaction of alcohols with sodium metal.

C13.6 Carboxylic acids:

a. Describe carboxylic acids as a homologous series with the general formula $C_nH_{2n+1}COOH$.

b. Be able to name, or recognise from the name, C1 to C6 straight-chain carboxylic acids.

c. Describe the chemical properties of carboxylic acids as those of weak acids, and so be able to predict their reactions and determine the formulae of their salts.

d. Know that carboxylic acids react with alcohols in the presence of an acid catalyst to produce esters.

C14. Metals

C14.1 Understand that the reactivity of a metal is linked to its tendency to form positive ions and the ease of extraction of the metal.

C14.2 Be able to use displacement reactions to establish the order of reactivity of metals and *vice versa*.

C14.3 Describe how the uses of metals are related to their physical and chemical properties, e.g. Al, Fe, Cu, Ag, Au, Ti, and understand that alloys can be formed to produce materials with specific properties.

C14.4 Know that most metal ores are the oxides of the metal, and that the extraction of metals always involves reduction processes.

C14.5 Know that common properties of transition metals include:

a. they are able to form stable ions in different oxidation states

b. they often form coloured compounds

c. they are often used as catalysts (as ions or atoms)

C15. Kinetic/Particle theory

C15.1 Be able to describe the packing and movement of particles in the three states of matter: solid, liquid and gas.

C15.2 Understand the changes to the packing and movement of particles in the following changes of state: freezing, melting, boiling/evaporating, and condensing. Understand that the energy required for these processes is related to the bonding and structure of the substance, including a consideration of intermolecular forces.

C16. Chemical tests

C16.1 Know and recognise the following tests for gases:

a. hydrogen – explodes with a 'squeaky pop' when a burning splint is held at the open end of a test tube
b. oxygen – relights a glowing splint
c. carbon dioxide – limewater turns cloudy when shaken with the gas
d. chlorine – damp blue litmus paper turns red and then is bleached (paper turns white)

C16.2 Know, recognise and describe the following tests for the anions:

a. carbonates – using a dilute acid
b. halides – using an aqueous solution of silver nitrate in the presence of dilute nitric acid (chlorides form a white precipitate; bromides form a cream precipitate; iodides form a yellow precipitate)
c. sulfates – using an aqueous solution of barium chloride in the presence of dilute hydrochloric acid

C16.3 Know and recognise the test for the following metal cations using aqueous sodium hydroxide:

a. Al^{3+}, Ca^{2+} and Mg^{2+} each form a white precipitate.
b. Cu^{2+} forms a blue precipitate.
c. Fe^{2+} forms a green precipitate.
d. Fe^{3+} forms a brown precipitate.

C16.4 Recall and recognise the flame test for the cations of the following metals:

Li (crimson red), Na (yellow-orange), K (lilac), Ca (red-orange), Cu (green)

C16.5 Know and recognise the test for the presence of water using anhydrous copper(II) sulfate (colour change from white to blue).

C17. Air and water

C17.1 Know and be able to use the composition of dry air, and understand that fractional distillation can be used to separate the components of air.

C17.2 Know the origins and describe the effects of greenhouse gases such as CO_2 and CH_4.

C17.3 Know the origins and effects of gaseous pollutants such as CO, CO_2, SO_2 and NO_x.

C17.4 Know the purpose of chlorine and fluoride ions in the treatment of drinking water.