Admissions Testing Service

NAZARBAYEV UNIVERSITY

# Foundation Year Programme

# Entrance Tests

# CHEMISTRY SPECIFICATION

# NUFYP SET 2017

V1.0 October 2016

# Chemistry

## 1. Atomic structure

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

1.2 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.

1.3 Know that atomic number = number of protons.

1.4 Know that mass number = number of protons + number of neutrons.

1.5 Understand that in an atom the number of protons = the number of electrons, so that atoms have no overall charge. Understand that in an ion the number of electrons is not equal to the number of protons, so ions have either a positive or a negative charge.

1.6 Use the standard notation (e.g. $^{12}_{6}C$) for any atom to calculate the number of protons, neutrons and electrons in an atom (and so any ion of the atom).

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

1.8 Define isotopes as atoms of an element with the same number of protons but different numbers of neutrons (so having different mass numbers). Use data to identify the relative abundances of isotopes.

1.9 Know and use the concept of relative atomic mass, $A_r$.

1.10 Use $A_r$ values to calculate the relative molecular (formula) mass, $M_r$, of a compound.

## 2. The Periodic Table (IUPAC)

2.1 Know that Periods are horizontal rows and Groups are vertical columns.

2.2 Recall the position of metals and non-metals in the Periodic Table.

2.3 Understand the use of displacement reactions in establishing the order of reactivity of metals.

2.4 Explain how the uses of metals are related to their physical and chemical properties, e.g. Al, Fe, Cu, Ag, Au, Ti.

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

2.6 Know the positions of the alkali metals (Group 1), the halogens (Group 17), the noble gases (Group 18) and the transition metals (*d*-block elements).

2.7 Know and use the relationship between the position of an atom in the Periodic Table (Group and Period) and the electronic configuration of the atom.

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

2.9 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.

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

2.11 Know the position in the Periodic Table of the transition metals (*d*-block elements) and their common properties (coloured ions, multiple stable ions, use as catalysts).

2.12 Demonstrate an understanding that elements with relative atomic masses that are not whole numbers (e.g. Cl) have isotopes that are responsible for this fact.

2.13 Calculate the relative atomic mass of an element from its isotopes given their relative isotopic masses and their relative abundances.

**3. Chemical reactions and equations**

3.1 Know and understand each of the following:

a. in a chemical reaction, new substances are formed by the rearrangement of atoms but none are destroyed or created. Energy may be absorbed or released by the reaction
b. a chemical reaction can be described using a word equation
c. the → symbol is used to show a reaction where all of the reactant can be converted into products (when the correct reacting amounts are used)
d. formulae for a compound can be written from:
    i. the names of many covalent compounds, e.g. $SO_3$ as sulfur trioxide
    ii. recall of the names of some common compounds, e.g. $H_2SO_4$ as sulfuric acid
    iii. the ionic charges for ionically bonded compounds. Cations (positive ions) for metal elements can be found from their Group number in the Periodic Table, as can the anions (negative ions) of non-metal ions. The charges of polyatomic anions need to be learnt, e.g. $CO_3^{2-}$ and $OH^-$. Where a cation can have more than one charge, e.g. Cu, Fe, then Roman numerals are used, e.g. iron(III) chloride as $FeCl_3$
e. word equations can be turned into balanced chemical equations using the formulae of compounds and the symbols of elements. [State symbols for each species in a chemical reaction can be added to a fully balanced chemical equation (s, l, g, aq).]
f. how to write balanced ionic equations either from a balanced chemical equation or to represent the processes, for example in electrolysis and redox
g. in some chemical reactions, all the reactants never turn into all the products. These equations use the symbol ⇌ and are called reversible
h. factors that can affect the position of the equilibrium and the rate at which the equilibrium is achieved (reactants, products, catalysts, temperature, pressure).

## 4. Quantitative Chemistry

4.1 Know that 1 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).

4.2 When given the molar volume of a gas (1 mole of any gas occupies 24 $dm^3$ at rtp and 22.4 $dm^3$ at stp), calculate mass or moles to volume and *vice versa*.

4.3 Calculate the percentage composition by mass of a compound given $A_r$ values.

4.4 Find the empirical formula of a compound given the percentage composition by mass of the elements present and the $A_r$ values. Find the molecular formula from the empirical formula if given the $M_r$ value.

4.5 Use balanced chemical equations to calculate the masses of reactants and products. Then perform scaling from the reacting ratio in the equation to find any reactant that may be in excess or amounts of reactants that completely react with each other (limiting reactants).

4.6 For balanced chemical equations involving only gases, be able to arrive at the mole ratio of reacting volumes of gases (or *vice versa*) or the ratio for the balanced equation as a whole.

4.7 For solutions, understand that concentration is in mol $dm^{-3}$ and be able to calculate the concentration given the moles (or grams) and the volume of water by using the equation:

$$\text{number of moles} = \frac{\text{volume in cm}^3}{1000} \times \text{concentration in mol dm}^{-3}$$

(or any of the other variations of this equation)

Or find any of the three quantities in the equation if given two of the others.

4.8 Know the meaning of the term *saturated*.

4.9 Calculate the percentage yield of a reaction using the balanced chemical equation and the equation:

$$\text{percentage yield} = \frac{\text{actual yield (g)}}{\text{predicted yield (g)}} \times 100$$

4.10 Be able to give logical reasons why, in practical situations, the percentage yield is rarely 100%.

## 5. Oxidation, reduction and redox

5.1 Know that on a basic level, oxidation is the gain of oxygen or the removal of hydrogen, and that reduction is the removal of oxygen or the addition of hydrogen.

5.2 Identify any reaction as being oxidation only, reduction only, redox (both oxidation and reduction taking place) or no change in oxidation/reduction.

5.3 Link oxidation and reduction to the transfer of electrons, i.e. reduction as a gain of electrons and oxidation as a loss of electrons.

5.4 Know how to determine the oxidation state of atoms in elements and simple compounds.

## 6. Chemical bonding, structure and properties

6.1 Know definitions of elements and of compounds, and the distinction between them.

6.2 Understand that the reason atoms react to form compounds is to attain the electronic configuration of a noble gas (the most stable configuration in the Periodic Table). Understand that the type of bonding taking place depends on the atoms involved in the reaction:

a. understand the characteristics of ionic, covalent (simple and giant) and metallic bonding, and recognise examples of each
b. understand the structure and properties of ionically, covalently (simple and giant) and metallically bonded structures.

## 7. Group Chemistry

7.1 Group 1 (alkali metals):

a. recognise that Group 1 metals are highly reactive, and then define metals as electron donors producing cations
b. describe the physical properties as being soft and having, for metals, relatively low melting and boiling points. Explain the need for storing the metals under oil (reaction with moist air)
c. know that reactivity increases down Group 1
d. describe what is observed when the metals react with:
    i. water
    ii. oxygen
    iii. Group 17 (halogens).

For the above reactions, write balanced chemical equations (including state symbols).

7.2 Group 17 (halogens):

a. recognise that the halogens are the most reactive non-metals (defining non-metals as acceptors of electrons and so forming anions)
b. know that reactivity decreases down the Group
c. explain what is meant by a displacement reaction (in terms of reactivity competition) and how the reactions between halogens and other halide ions can be used to establish the order of reactivity. Be able to write ionic equations for these reactions (including state symbols)
d. describe the tests for chloride, bromide and iodide ions using silver nitrate solution.

7.3 Group 18 (noble gases):

a. describe noble gases as the least reactive of the elements in the Periodic Table, and relate this to their electronic configurations.

7.4 Transition metals (*d*-block elements):

a. identify the position of the *d*-block elements in the Periodic Table
b. describe transition metals as having the following properties:
    i. form coloured compounds
    ii. used as catalysts.

**8. Separation techniques**

8.1 Know that chemical procedures are capable of separating:
   a. compounds (by chemical reactions, e.g. displacement or electrolysis)
   b. mixtures (defined as substances that may be mixed together but not chemically joined).

8.2 Know that mixtures include:
   a. liquids as *miscible* (can be separated by using fractional distillation because of the differences in boiling points) or *immiscible* (the layers can be removed one at a time using a separating funnel)
   b. soluble solids mixed with insoluble solids (using dissolving, filtering, evaporation, distillation and crystallisation).

**9. Acids, bases and salts**

9.1 Know the definitions, properties and reactions of acids and bases, including categorisations such as *strong*, *weak*, and *mono-/di-/tri-/poly- protic/basic*.

**10. Rates of reaction**

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

10.2 Know that the rate of reaction can be found by measuring the loss of a reactant or gain of a product measured over time.

10.3 Given the balanced chemical equation (including state symbols), be able to identify which reactant decrease or product increase can be measured, e.g. loss in mass, production of a gas, electrical conductivity or thermal conductivity. Describe practical procedures to measure such changes.

10.4 Recognise that catalysts are unchanged at the end of a reaction and are not used up in the reaction (although there may be some physical changes, e.g. lumps to powder).

**11. Energetics**

11.1 Understand the concepts of exothermic and endothermic reactions, their energy level profiles and the effect of catalysts on them.

**12. Electrolysis**

12.1 Be able to explain the terms *electrode*, *cathode*, *anode* and *electrolyte*.

12.2 Explain why direct current (dc) is used in electrolysis and not alternating current (ac).

12.3 Recognise that in electrolysis at the cathode the cations receive electrons (reduction) to change into atoms or molecules, and at the anode the anions lose electrons to form atoms or molecules (oxidation).

12.4 Be able to describe and explain the electrolysis process in electroplating using copper (copper sulfate).

**13. Carbon/Organic Chemistry**

*Candidates should know the IUPAC guidelines for the systematic naming of carbon compounds and apply the guidelines to be able to name all of the compounds referred to in this section of the Specification.*

13.1 Hydrocarbons:

a. Alkanes:

i. describe alkanes as being members of the same homologous series with the same general formula of $C_nH_{2n+2}$

ii. know that the term *saturated* is applied to alkanes because they only have single carbon-to-carbon bonds

iii. know that alkanes are chemically unreactive because of the stability of the C–C and C–H bonds

iv. know the IUPAC names of the straight-chain alkanes from $C_1$ to $C_6$ and be able to write their condensed formulae and their displayed structures

v. know that hydrocarbons burn in a plentiful supply of oxygen to produce only $CO_2$ and $H_2O$. Be able to write balanced chemical equations for these combustion processes, and know that an insufficient supply of oxygen will result in the formation of C and/or CO.

b. Alkenes:

i. describe alkenes as a homologous series with the general formula $C_nH_{2n}$

ii. know that alkenes contain a C=C double bond that makes them more reactive than alkanes

iii. know the IUPAC names of the straight-chain alkenes $C_2$ to $C_6$ and know how to write the name to show the position of the double bond in the chain

iv. know that the presence of the C=C bond makes them unsaturated and that the test for unsaturation is the ability to decolourise bromine water

v. be able to write the balanced chemical equation for the combustion of alkenes in a plentiful supply of oxygen

vi. recognise that the increased reactivity is due to the C=C bond opening up (to form a single bond) to enable other atoms to be added on, i.e. addition reactions

vii. know that addition reactions take place with hydrogen, halogens, hydrogen halides and steam, and be able to write the balanced chemical equations for these reactions as well as drawing the displayed formulae of the products formed.

13.2 Polymers:

a. know that alkenes or other molecules with a C=C bond will 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*

b. understand that polymers are giant molecules

c. given an unsaturated monomer molecule, be able to draw the structure of the polymer and *vice versa*

d. explain the terms *biodegradable* and *non-biodegradable* as applied to polymers, and explain the related pollution problems of their disposal, i.e. burning or landfill sites.

13.3 Alcohols and carboxylic acids:

a. know the general formulae

b. know chemical properties

c. know common uses.

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