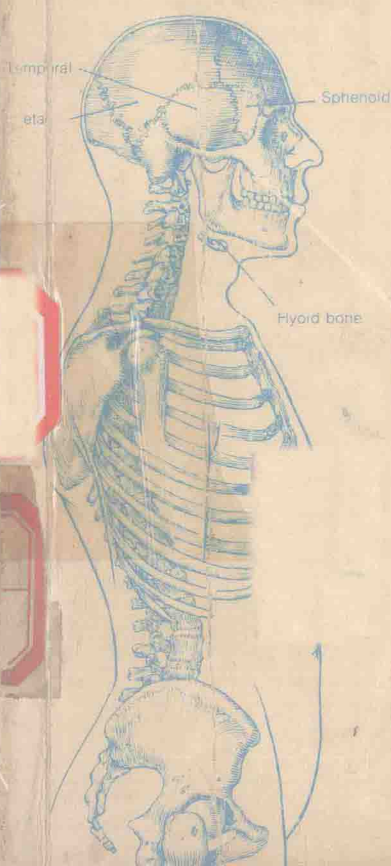
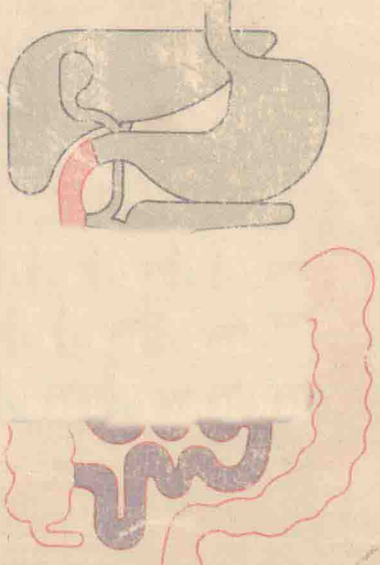
NURSES' AIDS SERIES

NAS

Anatomy & Physiology for Nurses

Sheila Jackson





Ninth Edition

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ANATOMY AND PHYSIOLOGY FOR NURSES

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BAILLIÈRE TINDALL · LONDON

A BAILLIÈRE TINDALL book published by
Cassell Ltd
35 Red Lion Square, London WC1R 4SG

and at Sydney, Auckland, Toronto, Johannesburg

an affiliate of
Macmillan Publishing Co. Inc.
New York

First published 1939
Ninth edition 1979

ISBN 0 7020 0737 4

ELBS edition 1979
(ISBN 0 7020 0738 2)
Sinhala edition (Official Language Affairs, Colombo) 1958
Turkish edition (Turkish Government) 1960
Spanish edition (C.E.C.S.A., Mexico) 1973
Hindi edition (N. R. Brothers, Indore) 1978

Printed in Great Britain by
Cox & Wyman Ltd., London,
Fakenham and Reading

British Library Cataloguing in Publication Data

Jackson, Sheila M
Anatomy and physiology for nurses.—9th ed.—(Nurses' aids series).
1. Human physiology
I. Title II. Armstrong, Katherine Fairlie
612'.002'4613 QP34.5

ISBN 0-7020-0737-4

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Anatomy and Physiology for Nurses

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ANAESTHESIA AND RECOVERY ROOM TECHNIQUES
ANATOMY AND PHYSIOLOGY FOR NURSES
EAR, NOSE AND THROAT NURSING
GASTROENTEROLOGICAL NURSING
GERIATRIC NURSING
MATHEMATICS IN NURSING
MEDICAL NURSING
MICROBIOLOGY FOR NURSES
MULTIPLE CHOICE QUESTIONS, BOOK 1
MULTIPLE CHOICE QUESTIONS, BOOK 2
NEUROMEDICAL AND NEUROSURGICAL NURSING
OBSTETRIC AND GYNAECOLOGICAL NURSING
OPHTHALMIC NURSING
ORTHOPAEDICS FOR NURSES
PAEDIATRIC NURSING
PERSONAL AND COMMUNITY HEALTH
PHARMACOLOGY FOR NURSES
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PSYCHIATRIC NURSING
PSYCHOLOGY FOR NURSES
SOCIOLOGY FOR NURSES
SURGICAL NURSING
THEATRE TECHNIQUE

Preface

Just under half a century ago, Katherine Armstrong, in the Preface to the First Edition stated her intent 'to provide nurses with a handbook which covers the syllabus of the General Nursing Council for England and Wales in human anatomy and physiology and which shall yet be a small volume at a reasonable price. Stress is laid throughout on the . . . approach which encourages the nurse to understand and not merely to memorize the knowledge necessary to pass her examinations, and makes her able to carry out her practical nursing work in an intelligent manner.' In this Ninth Edition, and its predecessor, I have sought to adhere to these basic principles. To meet the needs of today's reader and the new approach to the teaching of anatomy and physiology resulting from new knowledge and from consequent changes in the nurses' syllabus, substantial revision and rewriting were essential.

The earlier chapters introduce briefly some scientific principles which will help in the understanding of the chemistry of the body in later chapters. Here, and throughout the book, S.I. measurements are used, and the terminology adheres to the recommended English equivalent of the Paris *Nomina Anatomica*. In the chapter The Blood, I have incorporated new material on the reticulo-endothelial system, and the section on immunity has been expanded to include details of immune reactions (allergies) and autoimmunity. Further updating of the text involves pulmonary, portal and fetal circulation; the biliary system, its parts and function, in particular, the expansion of the section dealing with the pancreas. Nutrition and metabolism are given special emphasis in one chapter to underline their relationship. The chapter on the nervous system has been expanded and reorganized to facilitate understanding of this complex subject and additional information is included on the sensory system, special senses and sensation from skin and muscle, the meninges and cerebrospinal fluid. A list of Further Readings has been added for those students wishing to gain a little deeper knowledge of certain subjects.

I am extremely grateful for the willing help given by my typist Mrs. K. M. Webb, whose punctuality and encouragement have coerced me into completing the work within the allotted time. My thanks also go to my family for putting up with me during the writing of the book and to the publishers who always give their help so unstintingly.

December 1978 SHEILA M. JACKSON

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1 Elementary Physics and Chemistry

The nurse cares for human beings in illness and during vulnerable periods of their lives. In order to do this properly she needs to understand the structure and function of the body and to be able to relate this knowledge to her care of the patient. Each organ in the body plays its part in maintaining the health of the whole, and if one organ is at fault the whole body will be affected. The structure of each part suggests the function, and the function suggests the structure, so that the study of the human body is a logical process of thinking and reasoning, not merely of memorizing.

Terms. *Anatomy* is the study of the structure of the body and *physiology* is the study of its function. Some knowledge of elementary physics and chemistry will help in the study of anatomy and physiology and will also be needed to enable the nurse to care for the patient and to carry out nursing procedures. *Chemistry* deals with the composition of matter and the reactions between various types of matter. *Physics* deals with the behaviour and characteristics of matter, for example whether it gives off heat and light, or conducts electricity.

Matter

Matter is anything that can occupy space. When we refer to a 'space' we usually mean that it contains air, which can be displaced by other forms of matter. For example, an 'empty' bottle is not really empty as it contains air. A container from which the air has been extracted is called a vacuum.

Physical States of Matter

Matter has three physical states: (a) solid, (b) liquid and (c) gas.

A *solid* does not easily alter in either shape or size, e.g. stone, brick.

A *liquid* takes the shape of the vessel it is put into, but does not alter in size, e.g. 500 millilitres (ml) of water has no shape, but it takes the shape of the container it is put into; if it is put into a jug which will hold 1 litre the jug will not be filled.

A *gas* takes the shape and size of the vessel containing it. If the air is extracted from a container and a small quantity of gas is introduced the gas will expand to fill the container. If more gas is introduced the gas in the container is compressed, and the small particles which make up the gas are packed more closely together. More gas could be introduced until the flask bursts. A common example of this can be seen when a bicycle tyre is pumped up. After a few pumps the tyre seems full, but when someone gets on the bicycle the tyre goes flat because there is so little air in it. You can go on pumping until there is so much air in the tyre that when you get on the bicycle your weight does not flatten the tyre. A measured amount of gas in a cylinder will exert a known pressure. As the gas is used up the pressure in the cylinder will drop and it is in this way that the quantity of gas remaining in the cylinder can be gauged. Common examples of gases are oxygen, hydrogen and nitrogen.

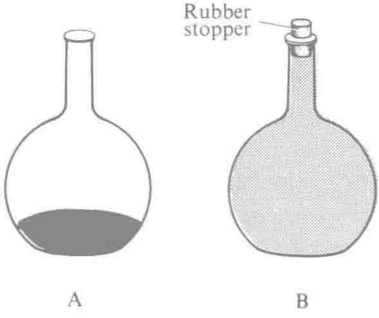

FIG. 1. Glass flasks each containing 100 millilitres of (A) fluid and (B) gas. Note how the gas expands to fill the flask.

Change of State

At normal temperatures iron is solid and water is liquid, but the state of matter can alter. The changes are due to heating or loss of heat. For example, liquid water becomes solid ice when heat is lost, and solid butter becomes liquid oil when it is warmed. The changes can be described as follows.

Melting is the change of a solid into a liquid as a result of heating, e.g. the turning of ice into water.

Evaporation is the change of a liquid into a gas as a result of heating, e.g. the turning of water into steam or water vapour. Gases formed by evaporation are called vapours.

Condensation is the turning of a gas into a liquid as a result of cooling, e.g. the turning of water vapour into water.

Consolidation is the turning of a liquid into a solid as a result of cooling, e.g. the turning of water into ice.

The first two of these changes, melting and evaporation, are due to heating, but the heat which causes this change of state does not cause any rise in the temperature of the matter. Heat is a form of energy and the energy in this case is used up in producing the change of state, so it does not heat the matter. For example, the temperature of melting ice is 0°C (32°F). When the ice melts the water is also at a temperature of 0°C. Water boils at 100°C (212°F). If you leave the kettle on the heat the water will not get any hotter because the added heat is used up in turning the water into water vapour. In the same way heat from the body evaporates the sweat from the skin, excess body heat is used up and the body is cooled. Heat used up in this way is called *latent heat*. In condensation or consolidation latent heat is set free.

Analysis and Synthesis

Earlier it was explained that chemistry is the study of the composition of matter. A chemist tries to split matter up into its various components to see what it is made of. This process is called *analysis*. He may also try to build up matter from its various components. This process is called *synthesis*. Synthetic substances are those which are made by man, e.g. plastics and nylon.

Elements, Compounds and Mixtures. Some substances cannot be split up and these substances are called *elements*. There are over ninety elements known to exist, including oxygen, carbon, nitrogen, iron, silver and gold. Substances which can be split into different elements are of two types: (a) compounds, and (b) mixtures.

A *compound* is a substance made of two or more elements which combine chemically to form a new substance with new properties. For example, hydrogen is a very light gas, used to fill balloons. It is highly inflammable and may explode. Oxygen is a gas which supports combustion but will not itself burn. These two gases in combination make a compound, water, which is a fluid, but it is not inflammable, will not explode, will not support combustion and will not burn. In fact it is very useful for putting out a fire. The elements which form a compound are always present in fixed proportions. For example, water consists of two parts of hydrogen combined with one part oxygen. If the proportions were altered a compound might be formed, but it would not be water. Two parts of hydrogen combined with two parts of oxygen give a compound called hydrogen peroxide which looks like water but has very different properties. Another characteristic of a compound is that it is not easy to separate the elements which compose it. To accomplish this separation a chemical change must take place.

A *mixture* is a substance made of two or more elements mixed together but not chemically combined. Air is a mixture of gases, mainly nitrogen and oxygen, with traces of carbon dioxide and other gases. A mixture has no new properties but simply those present in the elements which form the mixture. Air supports combustion because it contains free oxygen, but it does not support combustion as well as pure oxygen because of the high percentage of nitrogen, which will not support combustion. The elements in a mixture can be separated fairly easily because they are not chemically combined. Oxygen in air will support combustion because it is 'free' oxygen. Oxygen in water is not free and therefore will not support combustion. In a mixture there is no fixed proportion of elements composing it. Three different samples of air may contain three different proportions of oxygen, yet each is a specimen of air.

Common Elements. Among over ninety elements some are very rare, but there are a few common ones which should be known, with their symbols:

Barium	(Ba)	a malleable solid (metal)
Calcium	(Ca)	a solid (metal)
Carbon	(C)	a solid (non-metallic)
Hydrogen	(H)	a gas
Iodine	(I)	a solid (non-metallic)
Iron	(Fe)	a solid (metal)
Magnesium	(Mg)	a solid (metal)
Mercury	(Hg)	a liquid (metal)
Nitrogen	(N)	a gas

Oxygen	(O)	a gas
Potassium	(K)	a solid (metal)
Sodium	(Na)	a solid (metal)

Many of these elements are of interest to nurses. *Barium* is a metal. Its salts are opaque to X-rays and can be used for outlining the digestive tract for diagnostic purposes. *Calcium* is the mineral which makes teeth and bones hard. *Carbon* is rare as an element but is present in many compounds and in all living matter, including food. *Hydrogen* is a light, highly inflammable gas and when mixed with oxygen it forms an explosive mixture. *Iodine* is obtained from green food such as vegetables and is present in large quantities in seaweed. It is needed by the body to make the secretion of the thyroid gland. *Iron* is a metal and a small quantity is present in the body. It is necessary for the manufacture of the red cells in the blood and is important for health. Lack of iron is the most common cause of anaemia. *Magnesium* is found in small quantities with calcium in the bones and teeth. *Mercury* is poisonous to the body, but is useful in thermometers because it expands as it becomes warmer. *Nitrogen* is a gas which neither burns nor supports combustion; it is present in all living matter and must be present in our food supply. *Oxygen* is a gas which will not itself burn but which will support combustion; combustion is also called oxidation. *Potassium* is present in all living matter, particularly in plants. In the human body it is present in tissue cells. *Sodium* is also present in all living matter, but particularly in the animal world. In the body sodium is chiefly in the form of sodium chloride. There are approximately 4·5 grams (g) (1 teaspoon) of sodium chloride in 0·5 litre of body fluid (9 g to 1 litre = 0·9 per cent solution).

All compounds and mixtures are made of elements such as these. The body is made of very complicated chemical compounds built up from a small number of elements, so it is necessary for the student of anatomy and physiology to know a little about elements and compounds.

The Structure of Matter

All matter is made up of tiny particles called *molecules* which are so small that they cannot be seen with an ordinary microscope. Molecules are held together only by the attraction of one molecule to another, in the same way that a needle is held to a magnet. It is perhaps rather difficult to accept the fact that an iron bar is made of molecules which do not even adhere to each other but are only held together by mutual attraction. It is, however, an important concept which must be remembered. The force of attraction is called *cohesion* and must be distinguished from adhesion. A molecule is the smallest particle which can exist alone but which still has all the properties of the substance. For example, a molecule of water has all the properties of water which were mentioned earlier.

A molecule can be divided into smaller particles called *atoms*, but an atom cannot exist alone. A molecule of an element consists of atoms of that element, e.g. a molecule of oxygen consists of two atoms of oxygen (written O_2). A molecule of a compound consists of atoms of the different elements present in the compound, e.g. a molecule of water consists of two atoms of hydrogen and one atom of oxygen (written H_2O). A molecule of carbon dioxide consists of one atom of carbon and two atoms of oxygen (CO_2) and a molecule of glucose, which is a simple form of sugar, consists of six atoms of carbon, twelve atoms of hydrogen and six atoms of oxygen ($C_6H_{12}O_6$). These are examples of very simple chemical compounds.

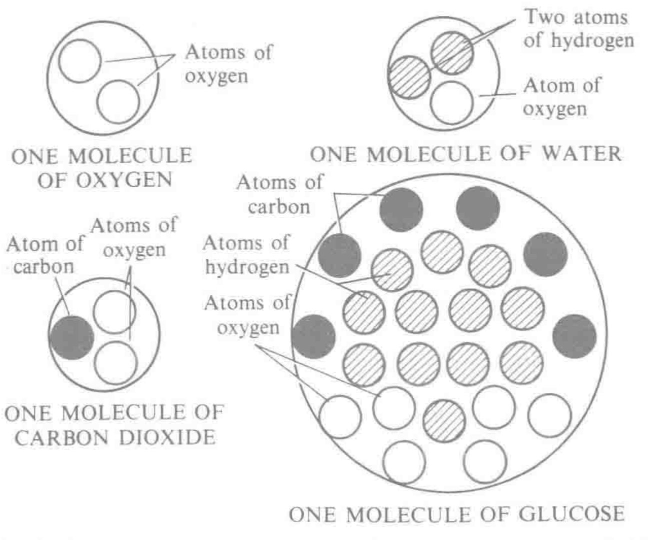

FIG. 2. Diagram to represent molecules of oxygen, water, carbon dioxide and glucose.

In the more complicated compounds which form the human body many elements may be present, and the number of atoms of any one element may run into hundreds. Although all molecules are very small they vary considerably in size and complexity.

Atomic Number and Atomic Weight. The word atom means indivisible and the name was given when scientists thought that the atom could not be divided. Now, however, more is known about the structure of an atom and most people have heard about 'splitting the atom' and its connection with atomic energy. An atom consists of even smaller particles of three different types, *protons* which carry a

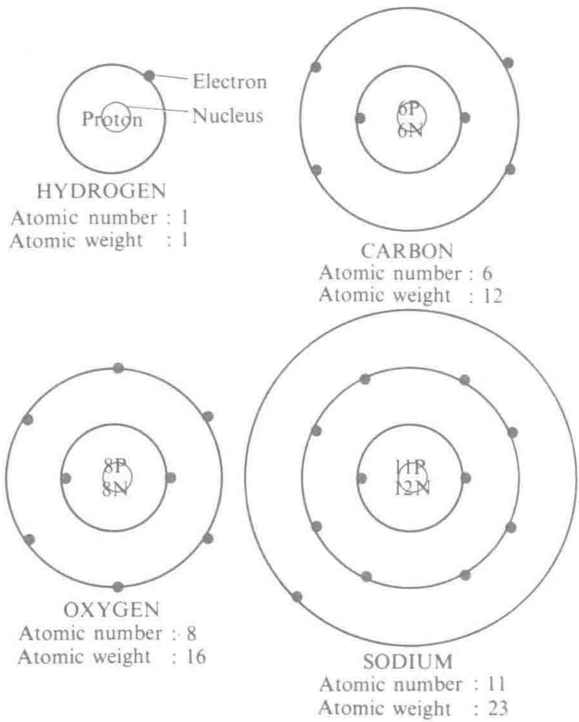

FIG. 3. Diagram of the structure of atoms of hydrogen, carbon, oxygen and sodium. P = proton; N = neutron.

positive electrical charge, *electrons* which carry a negative electrical charge and *neutrons* which are neutral. The protons and neutrons are massed together to form the nucleus of the atom, while the electrons whirl around the nucleus in one or more orbits known as shells. Different elements have different numbers of protons and electrons forming their atoms and the number of protons is equal to the number of electrons. This number is called the *atomic number*. Hydrogen has one proton in its nucleus and one electron circling round it and its atomic number is one. It has no neutron. Carbon has six protons and six neutrons in its nucleus and six electrons, arranged in two shells, circling round it, so its atomic number will be six. Sodium has eleven protons and twelve neutrons in the nucleus, and eleven electrons, in three shells, circling round it, so the atomic number is eleven. These numbers do not have to be memorized because they can be obtained from tables. The presence of neutrons in the nucleus does not affect the atomic number.

The weight of a neutron is roughly equal to the weight of a proton and the number of neutrons added to the number of protons gives the *atomic weight*. The weight of an electron is so small that it is not significant. Hydrogen has an atomic weight of one as it has one proton and one electron but no neutron. Carbon has an atomic weight of twelve as it has six protons and six neutrons in its nucleus. Sodium has an atomic weight of twenty-three as it has eleven protons and twelve neutrons in its nucleus.

Ions and Electrolytes. Atoms do not remain static as electrons may be split off from one atom and gained by another. Atoms are constantly gaining and losing electrons. When a substance is in solution in a fluid and an electron splits from an atom of the substance, an *ion* is formed. Substances which dissociate in this way are known as *electrolytes* because they carry small electric charges. Electrolytes are present in body fluids and are essential to life.

Gas Pressure

Earlier it was stated that one molecule is held to another by mutual attraction. The molecules of a solid are strongly attracted to one another so a solid does not easily alter in size or shape. The molecules of a liquid are less strongly attracted to each other so their positions can be altered more easily and the liquid takes the shape of the container. The molecules of a gas are attracted to each other very little so that when gas is put into a vacuum container the molecules separate from one another and fill the flask. If more gas is introduced the molecules become more densely packed and the gas is said to be under pressure. The pressure of gases is important in their use in the body. Unless oxygen is under sufficient pressure in the lungs it will not be transferred to the blood for transport round the body and the body tissues will suffer from lack of oxygen. On a high mountain the *pressure* of the air is so low that man cannot live without an extra supply of oxygen, though a candle will burn because there is sufficient quantity of air even though the pressure is reduced. In an airless room where there is reduced quantity of oxygen the candle will not burn, though man can continue to live as the oxygen present is still under pressure.

Solutions and Emulsions

When a lump of sugar is put into a cup of hot water the sugar dissolves and a *solution* of sugar is present in the cup. The molecules of sugar mix with the molecules of water until the sugar is evenly distributed throughout the fluid. The process can be speeded up by stirring, but the even distribution of sugar will occur eventually without any stirring. A measured quantity of fluid will only dissolve a measured quantity of another substance and when the fluid has dissolved as much as possible it is called a *saturated solution*. Fluids can dissolve solids, liquids and gases. Oxygen is dissolved in water, which enables fish to live in it. Heating a fluid drives off the dissolved gas, which appears at the surface as bubbles as the fluid gets hot. Water is the most common solvent and can dissolve a wide variety of substances, but substances which cannot be dissolved in water may be dissolved in other liquids. For example, water will not dissolve oil, but oil will dissolve in spirit. The fact that water is a common solvent makes it important in the body, two-thirds of which is water. Most of this water is in the cells which make up the body, some of it surrounds the cells, which can only live in a salt solution, called saline, and some is in the circulating blood and lymph.

An *emulsion* of oil is different from a solution. If oil is mixed with water the oil will rise to the top when stirring is stopped and will form a layer of pure oil on top of the water. If the oil is mixed with a solution of sodium carbonate (washing soda) an emulsion will be formed. The oil will be broken up into little droplets which will be suspended in the fluid and will not run together again. When allowed to stand the oil will still rise to the top, but the fat droplets will remain separated. Milk is a natural emulsion and the droplets of fat which form the cream can easily be seen under a microscope.

Acids and Alkalis

Substances may be either acid or alkaline in reaction, or they may be neutral (neither acid nor alkaline). The simplest agent used to detect the reaction of a substance is *litmus* which can be obtained as a fluid, but is conveniently used in the form of litmus paper. Blue litmus paper will turn pink when in contact with acid. Pink litmus paper will turn blue when in contact with an alkali. Neutral substances turn both pink and blue litmus paper into a purple colour. Every living cell must have the correct reaction if it is to survive. The blood and body tissues are slightly alkaline in reaction and vary little throughout life. If too much acid or too much alkali is present in the body illness will occur, and if there is an alteration in the reaction of the blood or body tissues death will follow. It is necessary to know the degree of acidity or alkalinity of certain substances and for this purpose a universal indicator is used. It changes colour from bright red, indicating a strong acid, to purple, which indicates strong alkali. These colour changes are spoken of as the pH of the substance being tested, and the scale runs from pH 1 for the strong acid to pH 14 for the strong alkali. Neutral is pH 7 and the pH of the blood is 7·4.

Pure water is neutral in reaction and as previously stated consists of molecules composed of two atoms of hydrogen and one atom of oxygen. Some of the molecules are broken up into smaller particles, e.g. hydrogen ions (H ions) or hydroxyl ions (OH ions). H ions have a positive electrical charge because the atoms have lost an electron and OH ions a negative electrical charge. In pure water the H ions and the OH ions are equal in number and the reaction is neutral. In some solutions H ions may outnumber OH ions and the reaction of the solution will be acid. If the OH ions outnumber the H ions the reaction will be alkaline. The pH shows the concentration of hydrogen ions (the '*H ion concentration*'), strong acids, e.g. hydrochloric acid, having a high H ion concentration, and strong alkalis, e.g. caustic soda, the highest concentration of hydroxyl ions (OH ions). Some substances, which slow down changes in reaction, are called '*buffer substances*'. In an alkaline solution such as body fluids, buffer substances neutralize acids or any excess of alkalis which may be added to it or produced in it. Examples of buffer substances are