Department of Environmental Science and Health

College of Science

University of Salahaddin

Subject: Instrumental Analysis

Course Book – 3rd Year Students

Lecturer's name:

Assist. Prof. Dr. Hijran Sanaan Jabbar

Academic Year: 2023 / 2024

Course Book

1. Course name	**Instrumental Analysis**
2. Lecturer in charge	**Theory: Dr. Hijran Sanaan Jabbar** **Practical: M. Sara A, M. Nigar A**
3. Department/ College	**Environmental Sciences - Science**
4. Contact	**e-mail: hijran.jabbar@su.edu.krd**
5. Time (in hours) per week	**Theory: 2** **Practical: 2**
6. Office hours	**Tuesday: 09:00 – 14:30** **Wednesday: 08:30 – 14:30** **Thursday: 08:30 – 14:30**
7. Course code	

8. Teacher's academic profile

Academic achievements and Qualifications: (starting from the most recent degree)

From- To	Degree	College-University	Country
2013 to date	PhD in Analytical Chemistry, Department of Chemistry	College of Science- University of Salahaddin	Iraq
2006 – 2013	M. Sc. in Analytical Chemistry, Department of Chemistry	College of Science- University of Salahaddin	Iraq
1997 – 2002	B.Sc. Chemistry, Department of Chemistry,	College of Science- University of Salahaddin	Iraq

Experiences: (starting from the most recent position), please mention Year, Position and Place

1- Assignments and Posts:

From- To	Post	Department -College	University
2018 to date	Assistant Professor	Department of Chemistry -College of Science	Salahaddin University
2013 – 2018	Lecture	Department of Chemistry -College of Science	Salahaddin University
2006-2013	Assistant Lecture	Department of Chemistry -College of Science	Salahaddin University
2002-2006	Reporter in Chemistry Department	Department of Chemistry -College of Science	Salahaddin University

2- Teaching Activities

No	Subject	Stage-College	University
1	Introduction to Analytical Chemistry – Volumetric Analysis	1st- year students / Environmental Department-College of Science	Salahaddin University
2	Computer Science (Theory and Practical)	1st- year students / Chemistry Department-College of Science	Salahaddin University
3	Environmental Application of Analytical Chemistry – Practical	1st- year students / Environmental Department -College of Science	Salahaddin University
4	Analytical Chemistry- Separation Methods – Practical	3rd- year students / Chemistry Department-College of Science	Salahaddin University
5	Analytical Chemistry- Gravimetric Analysis – Practical	2nd - year students / Chemistry Department-College of Science	Salahaddin University
6	Instrumental Analysis	3rd- year students / Environmental Department-College of Science	Salahaddin University

9. Keywords	Analytical chemistry, Volumetric analysis, Titration method (Neutralization titration, Precipitation titration, Oxidation-Reduction titration and Complexometric titration), Unit expression (Molarity, Normality, ppm…etc)

10. Course overview:

- Learn about the theory, instrumentation, and applications instrumental analysis.
- To gain experience acquiring, treating, and interpreting data.
- To gain experience reading and writing scientific documents and presenting orally.
- To gain exposure to a wide range of instrumental techniques and the fields associated with them.

11. Course objective:

- Gaining experiences how to select a suitable technique and method for analysis of a suitable real sample or pure compound and its additives.
- Comparing the techniques through its accuracy and precision.
- Comparing the techniques through its sensitivity and selectivity.

12. Student's obligation

- The students should have presence in all lectures and Labs.
- Every lecture the first 10 min should be debate about the previous lecture and the interested student (participant in the debate) take marks.
- The students have round trip to the central laboratories or factories (generally in the 2nd semester).

13. Forms of teaching

The teaching process is made through the use of Data show in addition of A white board notes by the lecturer. A leaflet consisting all the subjects Is given to the students.

14. Assessment scheme- Three term examination through the academic year (for theoretical part) (45 Marks total).
- Every week, 10 min debate on the previous lecture (theory and practical) (2 Marks).
- Five Quizzes through each semester (5 Marks).
- Attendances in the lecture (3 Marks)

15. Student learning outcome:

- Students know which technique can be use for a certain analysis, depending on the accuracy, precision, sensitivity and selectivity.
- Students can easily come in for work in the private sectors, e.g. clinical Lab., industrial Lab., environmental Lab., etc.

Today due to the technology students can learn more about the modern instruments e.g. (HPLC, GC, FAAS, FAES, UV-Vis-Spectrophotometry, Conductometry, Potentiometric, etc

16. Course Reading List and References

- Key references: Fundamentals of Analytical Chemistry. (By: Skoog and West)
- Useful references: Chemical Instrumentation. (By: Strobel)
- Magazines and review (internet): www.wekepedia, www.science.

17. The Topics:	Lecturer's name
1) Introduction to instrumental Analysis (Terms associated with chemical analysis; The relation between analytical chemistry and other branches of chemistry and other Sciences; Classification of instrumental techniques; Relation between technique- method and procedure).	1st Lecture
2) Feedback of the previous lecture (10 min); General considerations in evaluating: [Precision, Accuracy, Errors in instrumental analysis, Some statistical expressions, (e.g. Standard Deviation, Relative Standard Deviation, Variance, Relative Error, Recovery)].	2nd Lecture
3) Feedback of the previous lecture (10 min); General considerations in evaluating (continued): [Sensitivity, Selectivity, Linear calibration curve, Detection limit, Signal to noise ratio].	3rd Lecture ,
4) Feedback of the previous lecture (10 min); Molecular Spectroscopy: Properties of light; nature of electromagnetic radiation; Interaction between light and mater; UV, Visible and IR Spectroscopy (Principles, techniques, and applications).	4th Lecture
5) Feedback of the previous lecture (10 min);	5th Lecture

Molecular Absorption Spectroscopy, Beer's-Lambert law; Sensitivity enhancement by Beer's law; Instrumentation of optical methods: (Radiation sources, Wavelength selectors (Filters and monochromators), Cells and sampling devices, Detectors, Readout modules).	
6) Feedback of the previous lecture (10 min); Deviation from Beer's law: (Instrumental deviations, Chemical deviations); Selectivity and enhancing of it by either (changing a reagent, oxidation state, pH, or masking agent).	6th Lectures
7) Feedback of the previous lecture (10 min); Turbidimetry and Nephelometry.	7th Lecture
8) Feedback of the previous lecture (10 min); Molecular Emission Spectroscopy: - Principles, Energy transition levels when a molecule gains energy. - Requirements for fluorescence: (Structure rigidity, Temperature and solvent effects, Effect of pH (Chemical quenching), Instrumentation:, Fluorimeter Spectrofluorimeter).	8th Lecture
9) Feedback of the previous lecture (10 min); Molecular Emission Spectroscopy (Cont.): Phosphorescence and Chemiluminescence's (Theory, Instrumentations and Applications).	9th Lecture
10) Feedback of the previous lecture (10 min); Molecular Spectroscopy: Infrared (IR) spectrometry, Correlation of IR spectra with molecular structure, Instrumentation of IR, Applications (Quantitative and Qualitative Analysis).	10th Lecture
11) Feedback of the previous lecture (10 min); Atomic Spectroscopy: Principles (Bands spectra and line spectra); **Atomic Emission Spectroscopy (AES)**; Radiation sources (Flame, Electrical Arc and Spark).	11th Lecture
12) Feedback of the previous lecture (10 min); Atomic Spectroscopy (Cont.): Flame Photometry [Flame: (Types of fuels and oxidants, flame zones, mixing of fuels and oxidants, total combustion method); Instrumentation; Effect of Temp. in atomic emission].	12th Lecture

13) Feedback of the previous lecture (10 min); **Atomic Spectroscopy:** Atomic Absorption Spectroscopy (AAS): [Flame, Premixed type; Radiation source in AAS (H.C.L.); Compares between AES and AAS; Applications of AES and AAS (Direct calibration, Standard addition method)].	13th Lecture
14) Feedback of the previous lecture (10 min); **Atomic Spectroscopy:** Interferences of Atomic Spectroscopy: (Spectral interferences, ionization, chemical reactions inside the flame, self absorption).	14th Lecture
15) Feedback of the previous lecture (10 min); **Electrochemical techniques for analysis:** Potentiometric technique (Reduction- Oxidation (Redox) processes; Electrochemical cells; Reference electrodes; Indicator electrodes).	15th Lecture
16) Feedback of the previous lecture (10 min); **Electrochemical techniques for analysis:** Conductometry (Theory, Instrumentation, Applications	16th Lecture
17) Automated Methods of analysis Continuous flow analysis , flow injection analysis	17th Lecture
18. Practical Topics (May be ultered if necessary)	
1) General descriptions, importance of this Lab., Safety in the Lab., Hazards of the chemical compounds, etc. 2) Determination of essential water in $CuSO_4.5H_2O$: [This experiment is useful for determination of moisture and humidity in real samples (e.g. soil, natural products, meat, etc.)]. 3) Spectrophotometric Determination of Copper sulfate: (The aim of this experiment for applying the Beer's law and how can be find the concentration of unknown sample). **Finding the λ_{max} for solution of $CuSO_4.5H_2O$.** 4) How to draw the Calibration curve for finding out the concentration of unknown ($CuSO_4.5H_2O$)? 5) Spectrophotometric Determination of Iron in soil: (Using real sample for determination of a certain element (Iron for example), while the element react with suitable reagent (1,10-phenanthroline) to produce a color complex which can be detected	

spectrophotometrically using Beer's law. **Preparation of the real sample.**

6) **Preparation of the Calibration curve from a standard stock solution, and finding the concentration of Fe^{2+} in the real sample.**
7) Spectrophotometric determination of Chromium and Manganese in steel: [This is for the application of Beer's law in a mixture containing more than one species ($A_{total} = A_1 + A_2 + A_3 + ...+ A_n$)].
8) Determination of acetyl salicylic acid using Ultraviolet Spectrophotometry: (The method is based on the analysis of A.S.A. (Aspirin) in the presence of base (NaOH) into pure Salicylic acid (indirect method) the region is UV-region).
9) Determination of Sulfate ion (SO_4^{2-}) in water using turbid metric technique: (Application of molecular absorption for the turbid solution; finding the hardness of water).
10) Determination of Sodium and Potassium in soil using Flame Atomic Emission Spectrometry (FAES): [The method is selective toward detection of alkali and alkali earth metals; used for clinical, biological, and environmental analysis].
11) Determination of heavy metals (e.g. Lead, Cadmium, Zinc, etc.) in soil using Flame Atomic Absorption Spectrometry (FAAS): [The method is selective toward detection of heavy metals; used for clinical, biological, and environmental analysis].
12) pH-meter and its calibration: (The principle of potentiometric technique can be discussed for students, how the pH-meter can be calibrated, what is buffer solutions and how they can be used for the calibration).
13) Conductometric titration of HCl and CH_3COOH with NaOH, then determination of dissociation constant (K_a) for acetic acid: Conductivity is widely used for estimating the overall ion content in various sample of practical interest, but conductivity values can not indicate the concentration of a specific ion in the sample. Ion concentration can be determined by means of conductometric titration which based on the fact that the conductance of the solution depends on (mobility or ion conductance number of ions and dilution).

14) Determination of Phenol using Conductometric technique: (The same aim as mentioned in experiment No. 11, but hear the technique is used for determination of organic compounds). **15) Examination for the 1st semester (1st Group).** **Examination for the 1st semester (2nd Group).**	

19. Examinations:

1. Compositional:

Q.1// Explain why: **(Use necessary diagrams, equations, and graphs) (? Marks)**

1) A mercury electrode is not very useful for performing oxidations?

Ans. because Hg is too easily oxidized.

2) Photomultiplier tube is more sensitive than photo tube as a detector?

Ans. because it contain more than one dynodes.

3) The F^- ion selective electrode is selective at pH (5- 8) only?

Ans. At pH > 8.0 OH^- ion interfere, at pH < 5.0 H^+ ions also interfere in total fluoride determinations; here un-dissociated HF forms to which the electrode is not responsive.

4) A merged injection system typically consists of two injection valves that are used to load the reagent and sample, respectively?

Ans. This facilitates mixing and reaction development, and saves sample and reagent.

5) Electrochemical methods measure the activity rather than concentration?

Ans. to obtain real values, and activity coefficient is not equal to 1.0.

6) Glass electrode can not be used beyond pH 12?

Ans. Because glass electrode at pH > 12 become selective for Na^+ ion and not H^+ ion.

7) (TISAB) solution is added to the sample and standards in the potentiometric methods?

Ans. Because ISEs are susceptible to several interferences, therefore, TISAB serves to adjust the ionic strength and the pH.

8) Molecular spectrophotometric methods are more complicated than atomic spectrometric methods?

Ans. because most of the reagents make complexes with metals, or interferences has more appears in Molecular spectrophotometric.

9) U.V. lamp is used as source of radiation in fluorimetry?

Ans. to give more intensity radiation to the process which makes the method more sensitive.

10) Graphite furnace AAS provide an increase in sensitivity and improved safety compared to flame-AAS?

Ans. Because in graphite furnace AAS samples atomized by electro-thermal and not flame, but in flame AAS may be cause backfire and explosive in addition the flame zone may has different temp. region.

11) Nephelometry is more sensitive than turbidimetry?

Ans. Because in Neph.,N , can be measured independently of the power of the source, P_0, in contrast, Tur. measurement requires evolution of both P_0 and P because T (Turbidity) is proportional to conc. is dependent upon the ratio of P_0 & P [$T = \log P_0/P = kbC$; $N = P_{90} = kCP_0$]

12) Self absorption sometimes affects the analysis in (FAES) flame atomic emission spectroscopy?

Ans. In AES the type of flame is turbulent burner which has hot and cold places, in a very hot positions atoms are excited but in the cold positions the atoms are still in ground state, these atoms in the ground state has ability to absorb the emitted radiation from the excited atoms in the hot positions and form interferences.

13) Addition of low ionization compounds such as lithium to samples analyzed by atomic spectroscopy?

14) Luminol CL by H_2O_2 is known to be non-selective.

15) Nephelometry is more sensitive than turbidimetry.

16) Deviations will occur in Beer's law.

17) Spectrophotometric method has poor selectivity.

18) UV & Vis spectrophotometry have somewhat limited application for qualitative analysis.

19) IR Spectroscopy is widely employed as an identification technique.

20) FTIR (Fourier Transform IR) instrumentation is more precise.

Q.2// Give a list of common ions of environmental significance that can be analyzed by ion selective electrodes (ISE).

Ans.

Pollution Monitoring: CN, F, S, Cl, NO_3 etc., in effluents, and natural waters.

Agriculture: NO_3, Cl, NH_4, K, Ca, I, CN in soils, plant material, fertilisers and feedstuffs.

Food Processing: NO_3, NO_2 in meat preservatives.

Salt content of meat, fish, dairy products, fruit juices, brewing solutions.

F in drinking water and other drinks.

Ca in dairy products and beer.

K in fruit juices and wine making.

Corrosive effect of NO_3 in canned foods.

Detergent Manufacture: Ca, Ba, F for studying effects on water quality.

Paper Manufacture: S and Cl in pulping and recovery-cycle liquors.

Explosives: F, Cl, NO_3 in explosive materials and combustion products.

Q.3//Use a table to compare the similarities and differences between potentiometry, conductometry, and voltammetry. Consider the following comparisons: (a) The electrical measurement (e.g., current, potential, and charge), (b) The types of cells, (c) The fundamental equation employed for quantitative measurement, and (d) The ability for qualitative determination.

Ans. a) e.g., current, potential, and charge; b) galvanic and electrolytic; c) Nernst, Faraday, and Ohm's

Potentiometry	Conductometry	Voltammetry
a) Potential	Charge	Current
b) Galvanic and/ or electrolytic	Electrolytic	Electrolytic
c) Nernst equation	Ohm's equation	Nernst equation

d) Not used for qualitative	**Not used for qualitative**	**used for qualitative by measuring E¼**

Q.4// How can you solve the following problems Use necessary diagrams, graphs and equations:

i) Low selectivity of AES due to the chemical interferences.

Ans. Some chemical reactions results a refractory oxide which is very stable and for this stable interferences atomization is difficult. e.g. for determination of Ca^{2+} ion in the presence of PO_4^{3-} as interference a stable compound of $Ca_3(PO_4)_2$ will be form. This problem can be solve by adding La^{3+} which is react with PO_4^{3-} and Ca^{2+} remain free [($LaPO_4$) is produce because this compound is more stable than $Ca_3(PO_4)_2$ and La^{3+} acts as releasing agent].

ii) Un-selectivity of the spectrophotometric reagents?

Ans. by control of: either pH; or selecting a selective reagent; or change the oxidation state of the reagent.

iii) Ionization in atomic spectroscopy?

Ans. ionization: **eq.1**

$$MX \leftrightarrow M^{\bullet} + X^{\bullet} \quad \leftrightarrow \quad M^{*} \leftrightarrow M^{+} + e \leftrightarrow M^{+*} + e^{-}$$

atoms **Excited** **ions** **lines**

Hotter atomization means: more ionzation; emission from interferents

Using high energy for excitation the above reactions will occurs (form spectral line eq. 1). It must reverse eq.1 to form M^* excited and not ion, this process occurs by addition of Li which has low ionization energy or it ionized easily and produce a number of electrons which react with ions M^{+*} and return to form M^*.

Q.5// Describe the differences between the following and list any particular advantages possessed by one over the other: **(? Marks)**

i) Photo tube and photomultiplier tube as detector.

ii) Spectrophotometers and photometers.

Q.6// A) Distinction between: **(? Marks)**

i) Techniques and methods. **ii)** Accuracy and Precision.

iii) Spectroscopy and Spectrometry.

B) Draw the block diagram for the overall process of instrumental measurements, Give example. **(? Marks)**

C) Define the following (give suitable equations, figures, etc.): **(? Marks)**

i) Analytical sensitivity.

ii) Recovery.

iii) Detection limit.

Q.7// A compound of formula weight 280 g/mole absorbed 65% of the radiation at a certain wavelength in a 2.0 cm cell at a concentration of 15.0 µg/ml. Calculate the molar absorptivity at the wavelength. **(? Marks)**

Q.8// An 8.64 ppm solution of $FeSCN^{2+}$ has a transmittance of 0.295 when measured in a 1.0 cm cell at 580 nm. Calculate the molar absorptivity for the complex at this wavelength. **(? Marks)**

Q.9// What are the advantages and disadvantages of measuring maximum CL intensity? **(? Marks)**

Q.10// Write similarities and differences for both: i) colorimeter and turbidimeter; ii) flourimetry and nephelometry. **(? Marks)**

2. True or false type of exams:

Q.11// State the true or false from the following and correct the false: **(? Marks)**

1- Turbidimetric or nephelometric methods are widely used in the analysis of water.

True

2- There are two types of burners: a) Nebulizer; b) atomizer.

False; a) turbulent flow burner (total combustion) and b) laminar flow burner (premixed).

3- AAS has lower selectivity than AES.

False; AAS has higher selectivity.

4- Turbidimetry is more sensitive than Nephelometry.

False; Turbidimetry is less sensitive than Nephelometry.

5- Spectrophotometer is more sensitive than spectrofluorometer.

False; spectrofluorometer is more sensitive than Spectrophotometer; Spectrophotometer is less sensitive than spectrofluorometer.

6- Chemiluminescence is the production of light due to biological reaction.

False; CL is the production of light due to chemical reaction.

7- In graphite furnace AAS samples are atomized by flame atomization.

False; In graphite furnace AAS samples are atomized by electrical power (non flame).

8- All organic compounds are capable of absorbing electromagnetic radiation because all contain carbon and hydrogen atoms.

False; because all contain σ and pai

9- The F^- ion selective electrode is selective at pH > 8.0.

False; is selective at pH 5-8.

10- In Nephelometry and Turbidimetry, the intensity of radiation appearing at any angle depends upon the number of particles only.

False; not only, depends on number, size, shape.

11- Determination of nitrogen oxides bases on the reaction with ozone is an example of liquid-phase CL.

False; is an example of gas CL.

12- U.V. and Vis-spectrophotometry have somewhat limited application for qualitative analysis because deviation occurs in Beer's law.

False; because the number of absorption maxima and minima are relatively few.

13- Chemiluminesence reaction between sulfur dioxide and oxygen atoms are a suitable example of liquid-phase CL.

False; is an example of gas CL.

14- If the radiation includes two wavelengths (λ_1 & λ_2) the Beer's law is apply for each independently; if Є1 > Є2, the relation between A and C is normal straight relation.

False; the relation between A and C is normal straight relation when Є1 = Є2.

Q.12// Which of the following pairs of compounds is likely to absorb radiation at the longer wavelength? **(? Marks)**

1) acetone (CH_3COCH_3) or 2-butanone ($CH_3COCH_2CH_3$)?

Ans. **Give similar spectra in shape and intensity.**

2) benzene (C_6H_6) or naphthalene ($C_{10}H_8$)?

Ans. **Naphthalene have increased conjugation and so absorb at longer wavelengths than benzene.**

3) CH_3CH_2COOH or $CH_2 = CHCOOH$?

Ans. CH_2 = CHOOH has absorb radiation at the longer wavelength due to the double bonds.

4) CH_3CH_2CNS or $SNCCH_2CH_2CH_2CNS$?

Ans. **Absorption maximum due to the CNS group occurs at 245 nm with ε of 800 (1st molecule), in the 2nd molecule λ_{max} = 247 nm with ε=2000**

Q.13// Fill the following spaces: **(? Marks)**

1- X-rays causes the excitation of the **Core electron.**

2- X-rays are define as **short wavelength electromagnetic radiation produced by the deceleration of high energy electrons or by electronic transitions involving electrons in the inner orbital or atoms.**

3- AAS used in quantitative analysis by two ways: i) **direct calibration**; ii) **standard addition**

4- The major applications of X-ray spectroscopy is for **qualitative** analysis in the field of **medical imaging, airport security,** and **inspecting industrial welds. (or elemental analysis).**

5- Electro-thermal atomizer devices generally provide an **enhanced sensitivity.**

6- In graphite furnace AAS, samples are atomized by **electro-thermal** atomization.

7- Spectral interference in FAES causes to decrease the **selectivity** of the method. 8- Turbidimetric or nephelometric methods are widely used in the **analysis of water.**

8- Derivative spectroscopy applied in the uv and vis-regions for ……..

9- The absorbing groups in a molecule are called ……

10- Infrared Radiation uses are i) ……., ii) ……., and iii) …….

11- Factors Affect Φ_{fluor} are i)……., ii) ……., iii) …… iv) …… ., v) …… and vi) …….

12- The most applications of fluorescence methods are for ……., and …….

13- The most applications of scattering methods are i) ……, ii) ……., and iii) ……..

14- Complete the following tables: **(? Marks)**

№	**λ (cm)**	**υ (Sec^{-1})**	**$\bar{\upsilon}$(cm^{-1})**
a))	$4.5x10^{-5}$	…….	…….
b))	…….	$3x10^{13}$	…….
c))	…….	…….	$1x10^{8}$

3. Multiple choices:

Q.14// Choose the correct answer from the following: **(? Marks)**

1) Spectrofluorometer is more sensitive than spectrophotometer, because:

a) Spectrofluorometer has a filter as wavelength selector.

b) Spectrofluorometer has a tungsten lamp.

c) Spectrofluorometer can be used for determination of organic species only.

d) Non of them.

2) Chemiluminesence reaction between sulfur dioxide and oxygen atoms are a suitable example of: **a) Gas-phase CL.** b) Liquid-phase CL.

c) Solid-phase CL. d) Non of them.

3) In Nephelometry and Turbidimetry, the intensity of radiation appearing at any angle depends upon:

a) Number of particles. b) Size and shape of particles.

c) Relative refractive indexes of the particles. **d) All of them.**

4) Chemiluminescence is:

a) the production of light due to biological reaction.

b) the production of light due to chemical reactions.

c) the production of gases from atmosphere.

d) non of them.

5) Determination of nitrogen oxides bases on the reaction with ozone is:

a) an example of liquid-phase CL. b) an example of solid-phase CL.

c) an example of gas-phase CL. d) non of them.

6) Turbidimetry and Nephelometry are based upon:

a) the emission of radiation by a solution. B) the absorption of radiation by a solution.

c) the scattering of radiation by a solution. D) all of them.

7) Chemiluminesence reaction between luminol and hydrogen peroxide in basic medium are a suitable example of: **a) Liquid-phase CL.** b) Solid-phase CL.

c) Gas-phase CL. d) Non of them.

8) If the radiation includes two wavelengths (λ_1 & λ_2) the Beer's law is apply for each independently; if $\epsilon 1 > \epsilon 2$, the relation between A and C is:

a) normal straight relation. b) positive deviation occurs.

c) negative deviation occurs. d) all of them.

9) U.V. and Vis-spectrophotometry have somewhat limited application for qualitative analysis because:

a) deviation occurs in Beer's law. b) the number of absorption maxima and minima are large. **c) the number of absorption maxima and minima are relatively few.**
d) all of them

20. Extra notes: **1) This course is suitable for the 4th year students (B.Sc.). It gives the students fresh knowledge in their last year studies.** **2) This course is useful in different fields to get works in private sectors**
21. Peer review