# ROYAL CIVIL SERVICE COMMISSION
# BHUTAN CIVIL SERVICE EXAMINATION (BCSE) 2020
# EXAMINATION CATEGORY: TECHNICAL

## PAPER III: SUBJECT SPECIALISATION PAPER FOR CHEMISTRY

**Date** : February 27, 2021
**Total Marks** : 100
**Writing Time** : 150 minutes (2.5 hours)
**Reading Time** : 15 Minutes (prior to writing time)

**GENERAL INSTRUCTIONS:**

1. Write your Registration Number clearly and correctly on the Answer Booklet.
2. The first 15 minutes is to check the number of pages of the Question Paper, printing errors, clarify doubts and to read the instructions. You are NOT permitted to write during this time.
3. This paper consists of **TWO SECTIONS**, namely SECTION A & SECTION B:
   - **SECTION A** has two parts: Part I - 30 Multiple Choice Questions
     Part II - 4 Short Answer Questions

     All questions under SECTION A are COMPULSORY.
   - **SECTION B** consists of two Case Studies. Choose only **ONE** case study and answer the questions of your choice.
4. All answers should be written on the Answer Booklet provided to you. Candidates are not allowed to write anything on the question paper. If required, ask for additional Answer Booklet.
5. All answers should be written with correct numbering of Section, Part and Question Number in the Answer Booklet provided to you. Note that any answer written without indicating any or correct Section, Part and Question Number will NOT be evaluated and no marks would be awarded.
6. Begin each Section and Part on a fresh page of the Answer Booklet.
7. You are not permitted to tear off any sheet(s) of the Answer Booklet as well as the Question Paper.
8. Use of any other paper including paper for rough work is not permitted.
9. **You must hand over the Answer Booklet to the Invigilator before leaving the examination hall.**
10. This paper has **9 printed pages**, including this instruction page.

**GOOD LUCK!**

## SECTION A

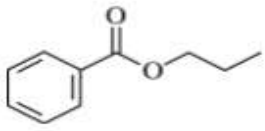
### PART I: Multiple Choice Questions [30 marks]

**Choose the correct answer and write down the letter of your chosen answer in the Answer Booklet against the question number e.g. 31 (d). Each question carries ONE mark. Any double writing, smudgy answers or writing more than one choice shall not be evaluated.**

1. Buffer solution is a combination of
   a) weak acid and its conjugate base.
   b) strong acid and its conjugate case.
   c) weak base and its conjugate acid.
   d) strong acid and its conjugate acid.

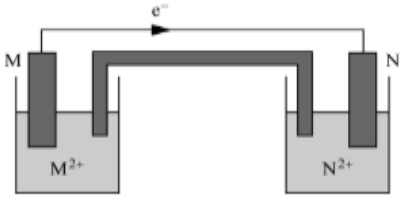
2. Which of the following combinations is commonly known as aqua regia?
   a) 1:3 Hydrochloric acid & Nitric acid
   b) 1:3 Nitric acid & Hydrochloric acid
   c) 1:2 Sulfuric acid & Boric acid
   d) 1:2 Ammonium hydroxide & Nitric acid.

3. According to IUPAC rules, the name of the molecule shown below is




   a) Benzyl propanoate.
   b) Phenyl proponoate.
   c) Propyl benzoate.
   d) Phenyl butanoate.

4. Which of the following is TRUE of the cell shown below?




   a) Metal M is being Oxidized
   b) Metal N is a reducing agent
   c) $M^{2+}$ ions are being reduced
   d) $N^{2+}$ ions are being oxidized

5. In a DNA double helix, guanine and cytosine are paired together by
   a) Covalent bond.
   b) Hydrogen bond.
   c) Peptide bond.
   d) Hyperconjugation bond.

6. From the following ions, which has the smallest radius?
   a) $K^+$
   b) $Ca^{2+}$
   c) $Sc^{3+}$
   d) $Rb^+$

7. Which of the following is/are TRUE about a binary liquid mixture that obeys Raoult's law?

   I. The partial pressure of each component at equilibrium is proportional to its mole fraction in the liquid mixture.

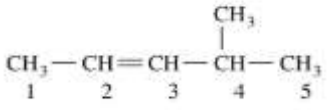
   II. Volume of mixture is equal to the sum of the volumes of each component before mixture.

   III. Intermolecular interactions in the mixture are identical to the intermolecular interactions in the pure components.

   a) I only
   b) II & III only
   c) I , II & III only
   d) I & III only

8. Elements with partially filled 4f and 5f orbitals include the following EXCEPT
   a) Cu
   b) Gd
   c) Eu
   d) Cm

9. In the compound shown below, which hydrogen is most easily abstracted during free radical bromination reaction?




   a) 1 & 5
   b) 2
   c) 3
   d) 4

10. Which of the following is NOT TRUE of the spontaneous process?
    a) The process is exothermic.
    b) The process does not involve any work.
    c) The entropy of the system increases.
    d) Total entropy of the system plus surrounding increases.

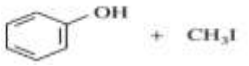
11. What is the maximum number of phases that can be at equilibrium of each other in three component mixtures?
    a) 1
    b) 2
    c) 3
    d) 4

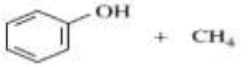
12. Infrared (IR) spectroscopy is useful in determining certain aspects of certain structure of organic molecules because
    a) all molecular bonds absorb IR radiations.
    b) IR Peak intensities are related to molecular mass.
    c) most organic functional groups absorb in the characteristic regions of IR Spectrum.
    d) each element absorbs IR at a characteristic region.

13. The rate, r, of a zero order chemical reaction A $\longrightarrow$ B can be expressed as which of the following?
    a) r= k In [A]
    b) r=k
    c) $r=k[A]^1$
    d) $r=k[B]^1$

14. Which of the following are the major products of the reaction shown below?


    a) 

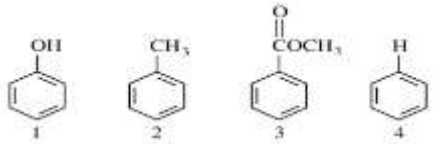
    b) 

    c) 

    d) 


15. Considering a 0.1M solution of each of the following, which solution will have the lowest pH?
    a) $Na_2CO_3$
    b) $Na_3PO_4$
    c) NaCl
    d) $CH_3COOH$

16. In which of the following are the molecules shown below listed in the order of increasing reactivity towards electrophilic aromatic substitution?




    a) 3<4<2<1
    b) 4<3<1<2
    c) 2<4<1<3
    d) 1<2<4<3

17. Cobalt-60 is used in the radiation therapy of cancer and can be produced by the bombardment of Cobalt-59 with which of the following?
    a) Alpha particles
    b) Beta particles
    c) Gamma particles
    d) Neutrons

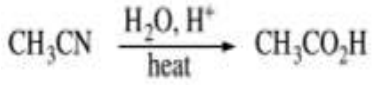
18. Anhydride of $Ba(OH)_2$ is
    a) BaO
    b) Ba
    c) BaOH
    d) $BaO_2$

19. Which of the following spectroscopy is a light-scattering technique?
    a) Nuclear magnetic resonance
    b) Infrared spectroscopy
    c) Raman
    d) Ultraviolet-visible

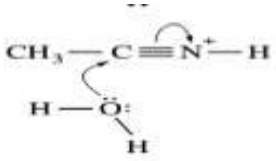
20. For EDTA titrations, the analyte solution and titrant solutions are both buffered at the same pH for which of the following reasons?
    I. The conditional formation constant is affected by Ph
    II. The fraction of EDTA in fully deprotonated $Y^{4-}$ varies with Ph
    III. When EDTA reacts to form a metal complex, $H^+$ is product in most of the cases

    a) I & II only
    b) II & III only
    c) I & III only
    d) I, II & III only

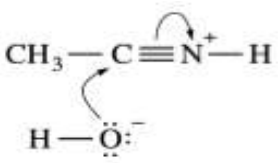
21. Which of the following best depict the initial nucleophilic addition step in acid-catalyzed hydrolysis of acetronitrile shown below?

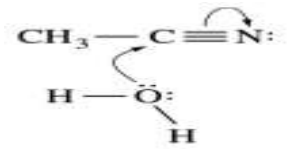


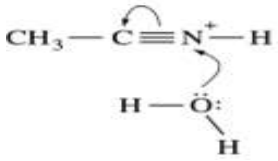
a)



b)

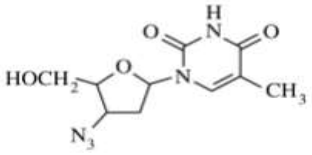


c) 

d) 

22. From the following compounds, which is LEAST likely to behave as a Lewis acid?
    a) $MgCl_2$
    b) $BeCl_2$
    c) $ZnCl_2$
    d) $SCl_2$

23. The compound shown below is XYZ, a drug used in the treatment of Acquired ImmunoDeficiency Syndrome (AIDS). What is the total number of stereoisomers for this compound?



    a) 4
    b) 6
    c) 8
    d) 10

24. The compound shown below is

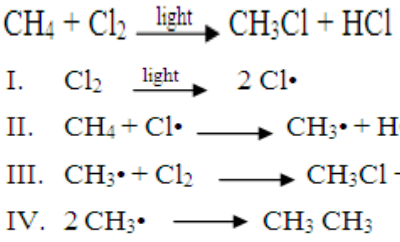
    a) Triglyceride
    b) Tripeptide
    c) Trinucleotide
    d) Trisaccharide

25. Of the following colligative properties, which is the most practical in determining the extent of protein aggregation?
    a) Osmotic pressure
    b) Boiling point elevation
    c) Freezing point depression
    d) Solute vapor pressure

26. An intern performs redox titrations and obtains a mean result of 0.110M for five titrations with a standard deviation of 0.001M. If the actual concentration of titrated solution is 0.100M, which of the following is TRUE?
    a) Accurate but not precise.
    b) Precise but not accurate.
    c) Not accurate and not precise.
    d) None of above.

27. Which of the following statements about the lanthanide element is NOT TRUE?
    a) The most common oxidation state of lanthanide element is +3
    b) Lanthanide complexes often have high coordination number.
    c) The atomic radii of lanthanide elements increase across the period.
    d) All of the above.

28. Which of the following are the propagation steps in the free radical steps in the reaction shown below?




    a) I & II
    b) I & III
    c) II & III
    d) III & IV

29. From the following atoms, which has the lowest electron affinity?
    a) O
    b) Ca
    c) Be
    d) Br

30. Which of the following is the primary standard for use in standardization of bases?
    a) Sulphuric acid
    b) Potassium hydrogen phthalate
    c) Nitric acid
    d) Ammonium hydrogen sulphate

## PART II – Short Answer Questions [20 marks]

**This part has 4 Short Answer Questions. Answer ALL the questions. Each question carries 5 marks.**

### Question 1

a) Define electronegativity? What is its trend for the period and group in a periodic table? (1.5 marks)

b) What are nanomaterials and its importance? What is the key difference between nanosciences and nanotechnology? (1.5 marks)

c) What is Grignard reagent? How is it prepared? Write two applications and examples. (2 marks)

### Question 2

a) What do you understand by hardness in water? What are the types and differences between two types? Which ions are responsible for the cause of these hardness? (2.5 marks)

b) Which titration is used for the determination of hardness in water? What is the indicator used? During this titration, which color is discharged at the end point? Why? (2.5 marks)

### Question 3

a) What is the difference between enantiomers and diastereomers? Give structural examples of each (2.5marks)

b) What is an invert sugar? (1 mark)

c) How many lattice points are there in a unit cell in each of the following lattices? (1.5 marks)

I. Face centered cubic
II. Face centered tetragonal
III. Body centered

### Question 4

a) How will you prepare 0.1N $H_2SO_4$ in 250mL? The purity of the acid is 95% and its density is 1.83g/cm3. What will be the volume required if you prepare the same concentration in molarity? (3.5 marks)

b) How will you prepare 0.5 Normal solution from the prepared solution (0.1N)? (1.5 marks)

## SECTION B: CASE STUDY [50 marks]

**Choose either Case I or Case II from this section. Each case study carries 50 marks. Mark for each sub-question is indicated in the brackets.**

### CASE I

Chromatography is a non destructive technique for separating complex mixtures into their individual fractions or components: the components to be separated are distributed between mobile and stationary phase facilitating the separation. In the ancient times, these techniques were used to separate components into colored bands but now, besides structures with embedded chromophores, other complex structures could be separated using chromatographic techniques.

1. What is the principle of chromatography? What are mobile phases and stationary phases? (5 marks)
2. Classify in general the chromatographic techniques and explain the principles of liquid chromatography. (15 marks)
3. What is the principle of HPLC? Pictorially represent each component sequentially explaining how concentration of components is determined. (15 marks)
4. What is the difference between Normal phase and Reverse phase Chromatography? (10 marks)
5. How will you prepare 10, 20, 30, 40 and 50 ppm of aflatoxin standard in 250mL methanol by sequential dilution of stock solution? (5 marks)

### CASE II

Distillation is a method for separating mixtures based on differences in the conditions required to change the phase of components of the mixture. The liquid is heated to force components, which have different boiling points into the gas phase. The gas is then condensed back into liquid form and further treated for the purification process.

1. What is the principle of distillation? How distillation is applied to separate compounds from complex mixtures. Explain with a diagram. (7 marks)
2. Define boiling point of a liquid? Under what condition will a liquid boil? (5 marks)
3. Why is it impossible to completely purify a mixture by a distillation? (5 marks)
4. What is a partial pressure? State Dalton's law of partial pressure and write down its applications. (10 marks)
5. A distillation flask contains a mixture boiled at $340^0$F. Calculate the value in degree centigrade. (3 marks)
6. Write down the principle, working, applications and advantages of steam distillation. (20 marks)

**TASHI DELEK**