**Practice MCAT**

# *Physical Sciences*

Passage I Gas laws

Passage II Chemical kinetics

Independent questions

Passage III House circuitry

Passage IV Colligative properties

Passage V Bernoulli’s principle

Independent questions

Passage VI pH meter

Passage VII Flexible endoscopy

Independent questions

**Physical Sciences**

**Number of Items: 52**

**Time Allowed: 70 minutes**

**DIRECTIONS:** Most questions in the Physical Sciences test are organized into groups, each preceded by a descriptive passage. After studying the passage, select the one best answer to each question. Some questions are not based on a descriptive passage and are also independent of each other. You should also select the one best answer to these independent questions. A periodic table is provided and you may consult it whenever you wish.

**Periodic Table of the Elements**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| IA | IIA |  |  |  |  |  |  |  |  |  |  | IIIA | IVA | VA | VIA | VIIA | VIIA |
| 1  **H**  1.0 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 2  **He**  4.0 |
| 3  **Li**  6.9 | 4  **Be**  9.0 |  |  |  |  |  |  |  |  |  |  | 5  **B**  10.8 | 6  **C**  12.0 | 7  **N**  14.0 | 8  **O**  16.0 | 9  **F**  17.0 | 10  **Ne**  20.2 |
| 11  **Na**  23.0 | 12  **Mg**  24.3 |  |  |  |  |  |  |  |  |  |  | 13  **Al**  27.0 | 14  **Si**  28.1 | 15  **P**  31.0 | 16  **S**  32.1 | 17  **Cl**  35.5 | 18  **Ar**  39.9 |
| 19  **K**  39.1 | 20  **Ca**  40.1 | 21  **Sc**  45.0 | 22  **Ti**  47.9 | 23  **V**  50.9 | 24  **Cr**  52.0 | 25  **Mn**  54.9 | 26  **Fe**  55.8 | 27  **Co**  58.9 | 28  **Ni**  58.7 | 29  **Cu**  63.5 | 30  **Zn**  65.4 | 31  **Ga**  69.7 | 32  **Ge**  72.6 | 33  **As**  74.9 | 34  **Se**  79.0 | 35  **Br**  79.9 | 36  **Kr**  83.8 |
| 37  **Rb**  85.5 | 38  **Sr**  87.6 | 39  **Y**  88.9 | 40  **Zr**  91.2 | 41  **Nb**  92.9 | 42  **Mo**  95.9 | 43  **Tc**  (98) | 44  **Ru**  101.1 | 45  **Rh**  102.9 | 46  **Pd**  106.4 | 47  **Ag**  107.9 | 48  **Cd**  112.4 | 49  **In**  114.8 | 50  **Sn**  118.7 | 51  **Sb**  121.8 | 52  **Te**  127.6 | 53  **I**  126.9 | 54  **Xe**  131.3 |
| 55  **Cs**  132.9 | 56  **Ba**  137.3 | 57  **La**\*  138.9 | 72  **Hf**  178.5 | 73  **Ta**  180.9 | 74  **W**  183.9 | 75  **Re**  186.2 | 76  **Os**  190.2 | 77  **Ir**  192.2 | 78  **Pt**  195.1 | 79  **Au**  197.0 | 80  **Hg**  200.6 | 81  **Tl**  204.2 | 82  **Pb**  207.2 | 83  **Bi**  209.0 | 84  **Po**  (209) | 85  **At**  (210) | 86  **Rn**  (222) |
| 87  **Fr**  (223) | 88  **Ra**  (226) | 89  **Ac**†  (227) | 104  **Rf**  (261) | 105  **Db**  (262) | 106  **Sg**  (266) | 107  **Bh**  (264) | 108  **Hs**  (277) | 109  **Mt**  (268) | 110  **Ds**  (281) | 111  **Uuu**  (272) | 112  **Uub**  (261) |  | 114  **Uuq**  (289) |  | 116  **Uuh**  (289) |  |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| \* | 58  **Ce**  140 | 59  **Pr**  140 | 60  **Nd**  144 | 61  **Pm**  144 | 62  **Sm**  150 | 63  **Eu**  152 | 64  **Gd**  157 | 65  **Tb**  158 | 66  **Dy**  162 | 67  **Ho**  164 | 68  **Er**  167 | 69  **Tm**  168 | 70  **Yb**  173 | 71  **Lu**  175 |
| † | 90  **Th**  232 | 91  **Pa**  231 | 92  **U**  238 | 93  **Np**  237 | 94  **Pu**  244 | 95  **Am**  243 | 96  **Cm**  247 | 97  **Bk**  247 | 98  **Cf**  251 | 99  **Es**  252 | 100  **Fm**  257 | 101  **Md**  258 | 102  **No**  259 | 103  **Lr**  262 |

**Passage I**

The ideal gas laws may be summed up as the ideal gas equation below:

PV = nRT

In many instances, the ideal gas equation can be used for actual gases provided certain conditions are met. However, under conditions of high pressure and/or relatively low temperature, gases behave differently than would be expected using the ideal gas equation. In these situations, the Van der Waals equation provides a better approximation:



where a and b are constants specific for each gas.

1. Two identical evacuated flasks of negligible weight are filled with different gases to the same pressure. One is filled with hydrogen and the other with propane. Compared with the first flask, the flask filled with propane weighs

A) 11 times more.

B) 22 times more.

C) the same.

D) 44 times more.

2. A soccer ball with initial pressure P and initial volume V is inflated with air until the pressure is 2P and the volume is 1.1V. Temperature is kept constant. The weight of air in the ball has increased by a factor of

A) 2.2

B) 1.1

C) 1.0

D) 2.0

3. Given that the critical temperature of oxygen is 154 K and its critical pressure is 50 atm, which of the following statements is/are true?

I. In a closed container at 154 K and 50 atm, the solid, liquid, and gaseous phases of oxygen are in dynamic equilibrium.

II. Oxygen can be compressed into a liquid at room temperature.

III. It can be reasoned that ammonia has a critical temperature above 154 K.

A) I is true

B) II and III are true

C) III is true

D) I and III are true

4. In the Van der Waals equation, the purpose of the nb term is to

A) take into account that gas molecules exert intermolecular attractive forces.

B) take into account that gas molecules have a finite volume.

C) take into account that gas molecules react chemically with each other and the equilibrium constant depends on P and T.

D) take into account Heisenberg’s uncertainty principle.

5.In the Van der Waals equation, the purpose of the n2a/V2 term is to

A) take into account that gas molecules exert intermolecular attractive forces.

B) take into account that gas molecules have a finite volume.

C) take into account that gas molecules react chemically with each other and the equilibrium constant depends on P and T.

D) take into account Heisenberg’s uncertainty principle.

**Passage II**

Consider the data in the table below, which pertain to the reaction A + B C. This equation may or may not be balanced.

|  |  |  |  |
| --- | --- | --- | --- |
| Experiment  no. | [A] | [B] | Initial rate of formation of C (M/s) |
| 1 | 0.10 | 0.10 | 4.0 x 10-5 |
| 2 | 0.10 | 0.20 | 4.0 x 10-5 |
| 3 | 0.20 | 0.10 | 16.0 x 10-5 |

6. The rate law for the reaction is

A) Rate = k[A][B]

B) Rate = k[A]2[B]

C) Rate = k[A]2

D) Rate = k[A][B]2

7. Which graph would show a linear relationship? (t stands for time.)

A) 1/[A] versus t

B) ln[A] versus t

C) [A] versus t

D) [A]2 versus t

8. The rate constant, k, is

A) 4.0 x 10-3 M-1s-1

B) 4.0 x 10-3 Ms-1

C) 4.0 x 10-5M-1s-1

D) 4.0 x 10-5 Ms-1

9. What is the half-life of A when the initial concentration of A is 0.2 M?

A) 15.7 mins

B) 18.4 mins

C) 20.8 mins

D) 23.5 mins

10. The mechanism of the above reaction most likely involves

A) a termolecular rate-determining step.

B) a bimolecular rate-determining step involving two molecules of A, followed by a fast step involving a molecule of B.

C) A fast step involving a molecule of A and a molecule of B, followed by a bimolecular rate-determining step involving another molecule of A.

D) a bimolecular rate-determining step involving a molecule of A and a molecule of B, followed by a fast step involving another molecule of A.

11. Which of the following statements is/are true?

I. k increases with activation energy.

II. k increases with temperature.

III. k decreases with increasing concentrations of products.

A) Only II is true

B) I and II are true

C) II and III are true

D) All are true

**Questions 12 to 15 are independent of any passage and of each other.**

12. Assume that the standard reduction potential for the reaction A3+ + e- A2+ is EoA, and the standard reduction potential for the reaction B+ + e- B is EoB. A solution initially containing [A3+] = 1.0 M, [A2+] 1.0 M, and [B+] = 1.0 M is agitated with excess solid B metal. When equilibrium is attained, the solution contains [A3+] = 0.7 M, [A2+] = 1.3 M, and [B+] = 1.3. Which of the following can be concluded?

A) EoA = EoB

B) EoA > EoB

C) EoA < EoB

D) EoA + EoB = 0

13. Which of the following has the greatest ionic character in its bonds?

A) RbCl

B) Li Cl

C) BCl3

D) Ca Cl2

14. Three children of mass 20 kg, 40 kg, and 60 kg want to balance themselves on a 8 m long see-saw, pivoted at its center. The 60 kg child sits 1 m from the left end. The 40 kg child sits at the right end. Where must the 20 kg child sit?

A) 3 m from the right end

B) 3 m from the left end

C) 1 m from the right end

D) 2 m from the right end

15. If the intensity of a sound goes up by 20 dB, how many times does the sound intensity increase?

A) 20 times

B) 1000 times

C) 10 times

D) 100 times

**Passage III**

Typically domestic electric power is first generated from fossil fuels, nuclear reactions, or falling water. An A.C. emf is produced which is stepped-up in voltage for long-distance transmission, then stepped down gradually so that finally each household receives 120V/240V power as shown in the simplified diagram below.

In the house depicted, there are three circuits: two 120V and one 240V. The wire labeled ‘d’ is the neutral wire, which is grounded. Assume all resistances are non-inductive.



16. The root-mean-square voltage between wires ‘a’ and ‘d’ is 120V. What is the peak voltage and mean square voltage between these wires, respectively? (Note: 2 = 1.4)

A) 170 V and 28,900 V2

B) 170 V and 14,400 V2

C) 240 V and 28,900 V2

D) 240 V and 14,400 V2

17. What is the root-mean-square current in wire ‘a’?

A) 30 A

B) 5 A

C) 20 A

D) 10 A

18. What is the root-mean-square current in wire ‘b’?

A) 30 A

B) 5 A

C) 20 A

D) 10 A

19. What is the root-mean-square current in wire ‘c’?

A) 30 A

B) 5 A

C) 20 A

D) 10 A

20. What is the root-mean-square current in wire ‘d’?

A) 0 A

B) 5 A

C) 20 A

D) 10 A

21. What is the average power consumption of the house?

A) 3 kW

B) 5 kW

C) 2 kW

D) 13 kW

**Passage IV**

Solutions have some unique properties that are termed colligative. These properties depend only on the ratio of the number of particles of solute and solvent and not on the identity of the solute.

22. Which is the correct ordering for the following solutions when listed from highest boiling point to lowest boiling point? (Ka of HF is 7.2x10-4.)

0.05 M Mg(NO3)2

0.10 M sucrose

0.15 M KCl

0.10 M NaI

0.05 M HF

A) Mg(NO3)2, KCl, NaI, HF, sucrose

B) KCl, NaI, Mg(NO3)2, sucrose, HF

C) NaI, KCl, Mg(NO3)2, sucrose, HF

D) KCl, Mg(NO3)2, NaI, sucrose, HF

23. The vapor pressure of water at 250oC is 23.6 mmHg. If 0.180 kg of glucose is added to 0.900 kg of water, what is the vapor pressure of this solution?

A) 23.1 mmHg

B) 24.1 mmHg

C) 22.5 mmHg

D) 22.2 mmHg

24. How much ethylene glycol (C2H6O2) must be added to 1 kg of water to depress the freezing point to -40oC? Assume the Kf of water is 1.9 K/m.

A) 0.9 kg

B) 0.87 kg

C) 130 g

D) 1.3 kg

25. 78 g of benzene (C6H6; vapor pressure at 20oC is 75 mmHg) are mixed with 184 g of toluene (C7H8; vapor pressure at 20oC is 22 mmHg). There is no chemical reaction. The vapor pressure of this mixture at 20oC is

A) 48.5 mmHg

B) 75 mmHg

C) 40 mmHg

D) 45 mmHg

26. A protein solution with concentration 80 g/L has an osmotic pressure of 0.0205 atm at 27oC. What is the approximate molecular weight of the protein? (The gas constant is 0.082 L-atm/K-mol.)

A) 96,000

B) 192,000

C) 48,000

D) 1,500

**Passage V**

Bernoulli’s equation can be used to describe the flow of water down a pipe. It is commonly expressed in the form below.

P1 + gh1 + ½v12 = P2 + gh2 + ½v22

Consider a dam that is used to generate hydroelectric power. Water flows down a pipe to turbines at the bottom, causing them to spin, which causes electromagnetic induction of emf in generator coils, producing electricity. The top of the pipe is practically at the level of the surface of the water behind the dam. Each minute 120,000 m3 of water drops a vertical distance of 45m. Assume the density of water is 1,000 kg/m3 and g is 10m/s2.

27. The sequence of energy transformations is best described as:

A) potential energy, rotational kinetic energy, translational kinetic energy, electrical energy.

B) hydrostatic energy, translational kinetic energy, rotational kinetic energy, electrical energy.

C) potential energy, translational kinetic energy, rotational kinetic energy, electrical energy.

D) potential energy, translational kinetic energy, rotational kinetic energy, electromagnetic radiation.

28. The difference in pressure between water at the top of the pipe and water coming out at the bottom is:

A) 450 kPa

B) 0 kPa

C) 45 kPa

D) 450 Pa

29. What is the velocity of water at the bottom of the pipe (assume the velocity at the top is zero)?

A) 900 m/s

B) 21 m/s

C) 35 m/s

D) 30 m/s

30. Theoretically, what is the maximum electrical power that can be generated with this flow of water?

A) 900 megawatts

B) 90 megawatts

C) 900 kilowatts

D) 90 kilowatts

31. If the bottom of the pipes became completely blocked, what would be the hydrostatic pressure in the pipes at that point?

A) 450 kPa

B) 0 kPa

C) 45 kPa

D) 450 Pa

32. Suppose that the power company wants to decrease the maximum amount of power available. Possible ways to accomplish this include:

I. Re-positioning the opening of the pipe at the reservoir to a certain depth below the surface of the water.

II. Attaching fins to the inside of the pipe to create turbulence.

III. Reducing the cross-sectional area of the pipe.

IV. Moving the power generator to a higher elevation so that the water falls a shorter vertical distance.

A) I, II, and III are correct

B) II, III, and IV are correct

C) I, III, and IV are correct

D) I, II, and IV are correct

**Questions 33 to 36 are independent of any passage and of each other.**

33. For an oxidation-reduction reaction, which of the following is a consistent set of relations?

A) Go<0, Eo>0, Keq<1

B) Go>0, Eo<0, Keq<1

C) Go<0, Eo<0, Keq<1

D) Go<0, Eo<0, Keq>1

34. Which of the following is not a basic physical quantity?

A) Luminous intensity

B) Temperature

C) Number of moles

D) Force

35. For a gas, the following is/are true:

I. kinetic energy is proportional to temperature

II. the velocity of a molecule is proportional to the 1/(square root of its molecular weight)

III. the velocity of a molecule is proportional to the square root of temperature

A) I and III

B) I and II

C) II and III

D) All are true

36. A stone is dropped into a well. Ten seconds later a splash is heard. How deep is the water level below the well opening (ignore the time taken for sound to travel)?

A) 1000 m

B) 500 m

C) 50 m

D) 200 m

**Passage VI**

Ion-selective chemical electrodes produce emf’s that depend on the concentration of specific ions in fluids under test. They, therefore, can be used to measure the concentration of specific ions. A pH meter uses a hydrogen ion-selective electrode that produces an emf according to the equation below, which is derived from the Nernst equation.

E = constant + 0.059 log10[H+]

where E is the emf and a temperature of 25oC is assumed.

pH meters are calibrated so that the effect of the constant term is cancelled out.

37. Which graph shows the correct relationship between E and [H+]?

A)



B)



C)



D)



38. If the pH of a solution is increased by 1.0, E will

A) increase by 59 mV.

B) decrease by 59 mV.

C) decrease by log100.059 mV.

D) This cannot be determined since the answer depends on the initial pH.

39. A 0.10 M solution of formic acid (CH2O2) has a pH of 2.38. What is the Ka of formic acid?

A) 1.8 x 10-3

B) 1.8 x 10-4

C) 1.8 x 10-5

D) 1.8 x 10-6

40. Phosphoric acid (H3PO4) has Ka1 = 7.5 x 10-3, Ka2 = 6.2 x 10-8, and Ka3 = 4.2 x 10-13. What is the pH of 1.0 M phosphoric acid?

A) 1.1

B) 3.5

C) 5.2

D) 6.8

41. What is the pH of 0.01 M trisodium phosphate (Na3PO4)?

A) 7.0

B) 8.4

C) 10.9

D) 12.2

**Passage VII**

Flexible endoscopes are used extensively in medicine to visualize internal structures such as the respiratory tract, upper gastrointestinal tract, and colon. The advantage of a flexible endoscope over a rigid endoscope is that it can bend and thus go around “corners.” This means less discomfort for the patient and the endoscope can be advanced farther into the cavity of interest.

An endoscope has a number of channels, e.g. for irrigation, suctioning, surgical manipulation, illumination, and imaging. Below is a diagrammatic representation of the imaging components of a relatively simple flexible endoscope.





Lens 1 focal length is -2 cm.

Lens 2 focal length is 1 cm.

Lens 3 can be easily removed and replaced with another lens. Also, the distance between the lens and the end of the optical fibers can be adjusted. Each optical fiber consists of a cylindrical core surrounded by a cladding. Light enters one end of a fiber and is total internally reflected repeatedly until it exits the fiber at the opposite end.

42. For the best image quality, the following conditions should be met.

I. The core of the fibers must not absorb a significant amount of light.

II. The cladding must have a higher optical density than the core.

III. Light rays must be incident on the core-cladding interface at angles of incidence greater than the critical angle.

IV. The endoscope must not be bent too acutely.

A) I, II, and III are correct

B) I, II, and IV are correct

C) I, III, and IV are correct

D) All are correct

43. The critical angle of the core-cladding interface is given by

A) critical angle = sin-1(ncladding/ncore)

B) critical angle = sin-1(ncore/ncladding)

C) critical angle = sin-1(1/ncore)

D) critical angle = sin-1(1/ncladding)

44. If each fiber core is 1 mm in diameter, ncore is 1.50, and ncladding is 1.20, what is the minimum length of light-absorbing material required at the ends of the fibers to prevent refraction of light into the cladding?

A) 1 mm

B) 1.33 mm

C) 1.5 mm

D) 2 mm

45. The principle of the optical system shown is that light from an object is focused by the two objective lenses (1 and 2) onto the plane at which the optical fibers terminate. This image is then transmitted through the optical fiber bundle to the eyepiece. If lenses 1 and 2 are 1 cm apart at their optical centers and lens 2 is 2 cm from the optical fiber bundle, how far away must the object be from lens 1 to form a sharp image on the end of the optical fiber bundle?

A) 1.0 cm

B) 1.5 cm

C) 2.0 cm

D) 2.5 cm

46. The effect of lens 1 is

I. to possibly reduce overall chromatic aberration

II. to produce a virtual, erect, and diminished image that is the object for lens 2

III. create a wider field of view

A) I and II are correct

B) I and III are correct

C) II and III are correct

D) I, II, and III are correct

47. When light has traveled the length of the optical fibers it exits the ends of them and passes through lens 3, which acts like a magnifying glass. If an observer chooses a lens of 50 diopters, how far should lens 3 be from the end of the optical fibers to form an image at infinity?

A) 2.0 cm

B) 2.5 cm

C) 3.0 cm

D) 3.5 cm

**Questions 48 to 52 are independent of any passage and of each other.**

48. A ball is thrown up in the air with a velocity of 10 m/s. Which of the following is true?

A) time in air is 1 s; maximum height is 5 m.

B) time in air is 1 s; maximum height is 10 m.

C) time in air is 2 s; maximum height is 5 m.

D) time in air is 2 s; maximum height is 10 m.

49. The effect of weightlessness can be produced by flying a plane in a circular arc (i.e. ascending then descending in a smooth motion). If the speed of the plane is constant at 100 m/s, what is the radius of the arc that must be flown?

A) 1,000 m

B) 10,000 m

C) 100 m

D) 1,500 m

50. Which of the following energy sublevels can contain the most electrons?

A) n=4, l=0

B) n=5, l=2

C) n=6, l=3, lm=+1

D) n=4, l=3

51. Tl decays by the emission of beta particles (half-life = 3.1 mins). As a result, Pb is produced. After 9.3 mins, an initially pure sample of Tl contains 7 g of PB) What was the approximate mass of the original sample?

A) 7 g

B) 8 g

C) 28 g

D) 32 g

52. The isoelectric point of glycine is 6.0. When glycine is in a buffer with a pH of 6.0, which form predominates?

A) H3N+-CH2-COO-

B) H2N-CH2-COOH

C) H3N+-CH2-COOH

D) H2N-CH2-COO-

**STOP.** IF YOU FINISH BEFORE TIME IS CALLED, CHECK YOUR WORK. YOU MAY GO BACK TO ANY QUESTION IN THE PHYSICAL SCIENCES TEST BOOKLET.

**Verbal Reasoning**

**Number of Items: 40**

**Time Allowed: 60 minutes**

**DIRECTIONS:** There are seven passages in the Verbal Reasoning test. Each passage is followed by several questions. After reading a passage, select the one best answer to each question. If you are not certain of an answer, eliminate the alternatives that you know to be incorrect then select an answer from the remaining alternatives. Indicate your selection by clicking on the answer bubble next to it.

**Passage I**

There is a confused notion in the minds of many persons that the gathering of the property of the poor into the hands of the rich does no ultimate harm, since in whoever hands it may be, it must be spent at last, and thus, they think, return to the poor again. This fallacy has been again and again exposed; but granting the plea true, the same apology may, of course, be made for blackmail, or any other form of robbery. It might be (though practically it never is) as advantageous for the nation that the robber should have the spending of the money he extorts, as that the person robbed should have spent it. But this is no excuse for the theft. If I were to put a turnpike on the road where it passes my own gate, and endeavor to exact a shilling from every passenger, the public would soon do away with my gate, without listening to any pleas on my part that it was as advantageous to them, in the end, that I should spend their shillings, as that they themselves should. But if, instead of outfacing them with a turnpike, I can only persuade them to come in and buy stones, or old iron, or any other useless thing, out of my ground, I may rob them to the same extent, and be, moreover, thanked as a public benefactor and promoter of commercial prosperity. And this main question for the poor of England - for the poor of all countries - is wholly omitted in every treatise on the subject of wealth.

Even by the laborers themselves, the operation of capital is regarded only in its effect on their immediate interests, never in the far more terrific power of its appointment of the kind and the object of labor. It matters little, ultimately, how much a laborer is paid for making anything; but it matters fearfully what the thing is, which he is compelled to make. If his labor is so ordered as to produce food, fresh air, and fresh water, no matter that his wages are low, the food and the fresh air and water will be at last there, and he will at last get them. But if he is paid to destroy food and fresh air, or to produce iron bars instead of them, the food and air will finally not be there, and he will not get them, to his great and final inconvenience. So that, conclusively, in political as in household economy, the great question is, not so much what money you have in your pocket, as what you will buy with it and do with it.

53. It can be inferred that the author probably favors

A) capitalism.

B) totalitarianism.

C) socialism.

D) anarchism.

54. According to the passage, the individual should be particularly concerned with

A) how much wealth he can accumulate.

B) the acquisition of land property rather than money.

C) charging the customer a fair price.

D) the quality of goods which he purchases with his funds.

55. The passage implies that

A) “A stitch in time saves nine.”

B) “It is better late than never.”

C) “He who steals my purse steals trash.”

D) “All’s well that ends well.”

56. It can be inferred that, in regard to the accumulation of wealth, the author

A) equates the rich with the thief.

B) thinks that there are few honest businessmen.

C) condones some dishonesty in business dealings.

D) believes destruction of property is good because it creates consumer demand.

57. What is the “main question for the poor” referred to by the author?

A) the use to which the laborer can put his money

B) the methods by which capital may be accumulated

C) the results of their work and their lack of authority to determine to what ends their work shall be put

D) whether full measure of recompense shall be accorded to the laboring person for the investment of his time in worthy work

58. According to the views expressed in the passage, people should be happiest doing which of the following?

A) mining ore for the manufacture of weapons

B) cleaning sewage ponds at a treatment plant

C) waiting tables for a rich man

D) helping a poor man do his job

**Passage II**

Shams and delusions are esteemed for soundest truths, while reality is fabulous. If men would steadily observe realities only, and not allow themselves to be deluded, life, to compare it with such things as we know, would be like a fairy tale and the Arabian Nights’ entertainments. If we respect only what is inevitable and has a right to be, music and poetry would resound along the streets. When we are unhurried and wise, we perceive that only great and worthy things have any permanent and absolute existence, that petty fears and petty pleasures are but the shadow of the reality.

This is always exhilarating and sublime. By closing the eyes and slumbering, and consenting to be deceived by shows, men everywhere establish and confirm their daily life of routine and habit, which still is built on purely illusory foundations. Children, who play life, discern its true law and relations more clearly than men who fail to live it worthily, but who think that they are wiser by experience; that is, by failure.

I have read in a Hindu book that there was a king’s son who, being expelled in infancy from his native city, was brought up by a forester, and, growing up to maturity in that state, imagined himself to belong to the barbarous race with which he lived. One of his father’s ministers, having discovered him, revealed to him what he was, and the misconception of his character was removed, and he knew himself to be a prince. “So soul,” continues the Hindu philosopher, “from the circumstances in which it is placed, mistakes its own character, until the truth is revealed to it by some holy teacher, and then it knows itself to be *Brahme*.

We think that that *is* which *appears* to be. If a man should give us an account of the realities he beheld, we should not recognize the place in his description. Look at a meeting-house, or a court-house, or a jail, or a shop, or a dwelling house, and say what that thing really is before a true gaze, and they would all go to pieces in your account of them. Men esteem truth remote, in the outskirts of the system, behind the farthest star, before Adam and after the last man. In eternity there is indeed something true and sublime. But all these times and places and occasions are now and here. God himself culminates in the present moment, and will never be more divine in the lapse of all ages. And we are enabled to apprehend at all what is sublime and noble only by the perpetual instilling and drenching of the reality that surrounds us. The universe constantly and obediently answers to our conceptions; whether we travel fast or slow, the track is laid for us. Let us spend our lives in conceiving then. The poet or the artist never yet had so fair and noble a design but some of his posterity at least could accomplish it.

59. The writer’s attitude toward the arts is one of

A) indifference.

B) suspicion.

C) admiration.

D) repulsion.

60. The author believes that children are often more acute than adults in their appreciation of life’s relations because

A) children know more than adults.

B) children can use their experience better.

C) children’s eyes are unclouded by failure.

D) experience is the best teacher.

61. The passage implies that human beings

A) cannot distinguish the true from the untrue.

B) are immoral if they are lazy.

C) should be bold and fearless.

D) believe in fairy tales.

62. The author is primarily concerned with urging the reader to

A) meditate on the meaninglessness of the present.

B) look to the future for enlightenment.

C) appraise the present for its true value.

D) honor the wisdom of past ages.

63. The passage is primarily concerned with problems of

A) history and economics.

B) society and population.

C) biology and physics.

D) theology and philosophy.

64. Which of the following best describes the author’s idea of the relationship between man and the universe?

A) Each person’s mind can control the galaxies.

B) What you see is what you get.

C) Our lives are predetermined.

D) We may choose to live quickly or slowly.

**Passage III**

The origin of continental nuclei has long been a puzzle. Theories advanced so far have generally failed to explain the first step in continent growth. Unfortunately, the geological evolution of the Earth’s surface has had an obliterating effect on the original composition and structure of the continents to such an extent that further terrestrial investigations have small chance of arriving at an unambiguous answer to the question of continental origin. Paradoxically, clues to the origin and early history of the surface features of Earth may be found on the moon and planets, rather than on Earth, because some of these bodies appear to have had a much less active geological history.

In the case of both the moon and Mars, it is generally concluded from the appearance of their heavily cratered surfaces that they have been subjected to bombardment by large meteoroids during their geological history. Likewise, it would appear a reasonable hypothesis that Earth has also been subjected to meteoroid bombardment in the past, and that very large bodies struck Earth early in its geological history.

The largest crater on the moon listed by Baldwin has a diameter of 285 km. However, if we accept the hypothesis of formation of some of the mare basins by impact, the maximum lunar impact crater diameter is probably as large as 650 km. Based on a lunar analogy, one might expect several impact craters of at least 500 km diameter to have been formed on Earth.

There is little doubt that the formation of a 500 km crater would be a major geological event. Numerous authors have considered the geological implications of such an event. Donn et al. have, for example, called on the impact of continent-size bodies of sialic composition to form the original continents. Two major difficulties inherent in this concept are the lack of any known sialic meteorites, and the high probability that the energy of impact would result in a wide dissemination of sialic material, rather than its concentration at the point of impact.

Gilvarry, on the other hand, called on meteoroid impact to explain the production of ocean basins. The major difficulties with this model are that the morphology of most of the ocean basins is not consistent with impact, and that the origin and growth of continents are not adequately explained.

We agree with Donn et al. that the impact of large meteorites or asteroids may have caused continent formation, but would rather think in terms of the localized addition of energy to the system, rather than in terms of the addition of actual sialic material.

65. The author’s purpose in writing the passage was to

A) analyze ways in which asteroids and meteorites could have influenced the development of continents on Earth.

B) discuss the possible causes of continent formation.

C) review lunar continent formation.

D) discuss the theories of continental nuclei formation.

66. A mare basin is most probably

A) an area where animal life flourished at one time.

B) a formula for determining the relationship between the depth and width of craters.

C) a valley that is filled in when a spatial body.

D) an area of the moon that is the result of collision between the moon and some other body.

67. The passage is primarily concerned with

A) the origin of continents on Earth.

B) the origin of craters on the moon.

C) differences of opinion among schools of geological thought.

D) the relationship between asteroids and meteorites and other space bodies.

68. The writer does not believe that

A) an asteroid is larger than a meteorite.

B) material from space, upon hitting the Earth, was eventually distributed.

C) oceans were formerly craters.

D) Earth, at one time, had craters.

69. It may be inferred from the passage that the author believes geologists researching continental origins and development would do well to devote much, if not most, of their study to

A) asteroids and large meteorites.

B) Earth.

C) the sun.

D) other planets and the moon.

**Passage IV**

The Planning Commission asserts that the needed reduction in acute care hospital beds can best be accomplished by closing the smaller hospitals, mainly voluntary and proprietary. This strategy follows from the argument that closing entire institutions saves more money than closing the equivalent number of beds scattered throughout the health system.

The issue is not that simple. Larger hospitals generally are designed to provide more complex care. Routine care at large hospitals costs more than the same care given at smaller hospitals. Therefore, closure of all the small hospitals would commit the city to paying, considerably more for inpatient care delivered at acute care hospitals than would be the case with a mixture of large and small institutions. Since reimbursement rates at the large hospitals are now based on total costs, paying the large institutions a lower rate for routine care would simply raise the rates for complex care by a comparable amount. Such a reimbursement rate-adjustment might make the charges for each individual case more accurately reflect the actual costs, but there would be no reduction in total costs.

There is some evidence that giant hospitals are not the most efficient. Service organizations – and medical care remains largely a service industry - frequently find that savings of scale have an upper limit. Similarly, the quality of routine care in the very largest hospitals appears to be less than optimum. Also, the concentration of all hospital beds in a few locations may affect the access to care.

Thus, simply closing the smaller hospitals will not necessarily save money or improve the quality of care. Since the fact remains that there are too many acute care hospital beds in the city, the problem is to devise a proper strategy for selecting and urging the closure of the excess beds, however many it may turn out to be. The closing of whole buildings within large medical centers has many of the cost advantages of closing the whole of smaller institutions, because the fixed costs can also be reduced in such cases. Unfortunately, many of the separate buildings at medical centers are special use facilities, the relocation of which is extremely costly. Still, a search should be made for such opportunities.

The current lack of adequate ambulatory care facilities raises another possibility. Some floors or other large compact areas of hospitals could be transferred from inpatient to ambulatory uses. Reimbursement of ambulatory services is chaotic, but the problem is being addressed.

The overhead associated with the entire hospital should not be charged even pro rata to the ambulatory facilities. Even if it were, the total cost would probably be less than that of building a new facility. Many other issues would also need study, especially the potential over-centralization of ambulatory services. The Planning Commission language seems to imply that one reason for closing smaller hospitals is that they are “mainly voluntary and proprietary,” thus preserving the public hospital system by making the rest of the hospital system absorb the needed cuts. It is important to preserve the public hospital system for many reasons, but the issue should be faced directly and not hidden behind arguments about hospital size, if indeed that was the Commission’s meaning.

70. The Planning Commission is accused by the author of being

A) unfair.

B) racist.

C) foolish.

D) shortsighted.

71. On the subject of the number of hospital beds, the author

A) is in complete agreement with the Planning Commission.

B) wishes to see large numbers of beds closed.

C) wishes to forestall the closing of any more hospital beds.

D) is unsure of the number of excess beds there really are.

72. All of the following are reasons the author opposes the Planning Commission’s recommendation except

A) Service industries have an upper limit for savings of scale.

B) Single buildings of large centers may be closable instead of smaller hospitals.

C) public hospitals have a unique contribution to make and should not be closed.

D) the smaller hospitals recommended for closure provide services more cheaply than larger hospitals.

73. With which of the following would the author probably not agree?

A) Large medical centers provide better and more complex care than smaller hospitals.

B) Reimbursement rates do not necessarily reflect the actual costs of providing medical care to a given patient.

C) Patients needing only routine medical care can often be distinguished from those requiring complex care prior to hospitalization.

D) Too much centralization of ambulatory care is possible.

74. The author’s purpose in discussing ambulatory care is to

A) discuss alternatives to closing hospital beds.

B) present a method of reducing the fiscal disadvantages of closing only parts of larger hospitals.

C) show another opportunity for saving money.

D) help preserve the public hospital system.

75. With which of the following is the author least likely to agree?

A) a proposal to save costs in a prison system by building only very large prison complexes

B) a plan to stop the closing of any hospital beds whatsoever in the city until the costs of various alternatives can be fully considered

C) an order by the Planning Commission mandating that no public hospitals be closed

D) a proposal by an architecture firm that new hospital buildings have centralized record systems

**Passage V**

Every profession or trade, every art, and every science has its technical vocabulary, the function of which is partly to designate things or processes which have no names in ordinary English, and partly to secure greater exactness in nomenclature. Such special dialects, or jargons, are necessary in technical discussion of any kind. Being universally understood by the devotees of the particular science or art, they have the precision of a mathematical formula. Besides, they save time, for it is much more economical to name a process than to describe it. Thousands of these technical terms are very properly included in every large dictionary, yet, as a whole, they are rather on the outskirts of the English language than actually within its borders.

Different occupations, however, differ widely in the character of their special vocabularies. In trades and handicrafts and other vocations, such as farming and fishing, that have occupied great numbers of men from remote times, the technical vocabulary is very old. It consists largely of native words, or of borrowed words that have worked themselves into the very fiber of our language.

Hence, though highly technical in many particulars, these vocabularies are more familiar in sound, and more generally understood, than most other technicalities. The special dialects of law, medicine, divinity, and philosophy have also, in their older strata, become pretty familiar to cultivated persons, and have contributed much to the popular vocabulary. Yet, every vocation still possesses a large body of technical terms that remain essentially foreign, even to educated speech. And the proportion has been much increased in the last fifty years, particularly in the various departments of natural and political science and in the mechanic arts. Here new terms are coined with the greatest freedom, and abandoned with indifference when they have served their turn. Most of the new coinages are confined to special discussions, and seldom get into general literature or conversation. Yet, no profession is nowadays, as all professions once were, a closed guild. The lawyer, the physician, the man of science, the cleric, all associate freely with his fellow creatures, and do not meet them in a merely professional way.

Furthermore, what is called “popular science” makes everybody acquainted with modern views and recent discoveries. Any important experiment, though made in a remote or provincial laboratory, is at once reported in the newspapers, and everybody is soon talking about it as in the case of the Roentgen rays and wireless telegraphy. Thus, our common speech is always taking up new technical terms and making them commonplace.

76. Which of the following words is least likely to have started its life as jargon?

A) sun

B) calf

C) plow

D) loom

77. The author’s main purpose in the passage is to

A) describe a phenomenon.

B) argue a belief.

C) propose a solution.

D) stimulate action.

78. When the author refers to professions as no longer being “closed guilds” he means that

A) it is much easier to become a professional than in the past.

B) there is more social intercourse between professionals and others.

C) popular science has told its secrets to the world.

D) anyone can now understand anything in a profession.

79. If the author of the passage wished to study a new field, he would probably

A) call in a dictionary expert.

B) become easily discouraged.

C) look to the histories of the words in the new field.

D) pay careful attention to the new field’s technical vocabulary.

80. It seems that the passage implies that

A) English is always becoming larger and larger.

B) the words of the English language are always changing.

C) one can never be sure of what a word means without consulting an expert.

D) technical terms in most non-scientific fields have little chance of becoming part of the main body of the language in these scientific days.

**Passage VI**

Suppose you go into a fruiterer’s shop wanting an apple. You take up one, and on biting it you find it is sour; you look at it, and see that it is hard and green. You take up another one, and that, too, is hard, green, and sour. The shopman offers you a third; but, before biting it, you examine it, and find that it is hard and green, and you immediately say that you will not have it, as it must be sour, like those that you have already tried.

Nothing can be simpler than that, you think; but if you will take the trouble to analyze and trace out into its logical elements what has been done by the mind, you will be greatly surprised. In the first place you have performed the operation of induction. You found that, in two experiences, hardness and greenness in apples went together with sourness. It was so in the first case, and it was confirmed by the second.

True, it is a very small basis, but still it is enough from which to make an induction; you generalize the facts, and you expect to find sourness in apples where you get hardness and greenness. You found upon that a general law, that all hard and green apples are sour; and that, so far as it goes, is a perfect induction. Well, having got your natural law in this way, when you are offered another apple, which you find, is hard and green, you say, “All hard and green apples are sour; this apple is hard and green, therefore, this apple is sour.” That train of reasoning is what logicians call a syllogism, and has all its various parts and terms - its major premise, its minor premise, and its conclusion. And, by the help of further reasoning, which, if drawn out, would have to be exhibited in two or three other syllogisms, you arrive at your final determination, “I will not have that apple.” So that, you see, you have, in the first place, established a law by induction, and upon that you have founded a deduction, and reasoned out the special particular case.

Well now, suppose, having got your conclusion of the law, that at some times afterwards, you are discussing the qualities of apple with a friend; you will say to him, “It is a very curious thing, but I find that all hard and green apples are sour!” Your friend says to you, “But how do you know that?” You at once reply, “Oh, because I have tried them over and over again, and have always found them to be so. Well, if we were talking science instead of common sense, we should call that an experimental verification. And, if still opposed, you go further and say, “I have heard from the people in Somersetshire and Devonshire, where a large number of apples are grown, and in London, where many apples are sold and eaten, that they have observed the same thing. It is also found to be the case in Normandy, and in North America. In short, I find it to be the universal experience of mankind wherever attention has been directed to the subject.” Where upon, your friend, unless he is a very unreasonable man, agrees with you, and is convinced that you are quite right in the conclusion you have drawn. He believes, although perhaps he does not know he believes it, that the more extensive verifications have been made, and results of the same kind arrived at - that the more varied the conditions under which the same results are attained, the more certain is the ultimate conclusion, and he disputes the question no further. He sees that the experiment has been tried under all sorts of conditions, as to time, place, and people, with the same result; and he says with you, therefore, that the law you have laid down must be a good one, and he must believe it.

81. The author has the approach of a(an)

A) scientist.

B) artist.

C) novelist.

D) economist.

82. The term “natural law” as it appears in the passage refers to

A) common sense.

B) the “honor system.”

C) the result of an induction.

D) the order of nature.

83. Apples are used

A) in order to convince the reader that fruit has no intellect.

B) to illustrate the subject of the passage.

C) to give color to the story.

D) to show how foolish logic is.

84. If you find a hard and green apple that is not sour, you should

A) try further apples to see if the natural law has changed.

B) eat the rest of the apple at once.

C) reject the law stating hard and green apples are usually sour.

D) conduct further investigations and make adjustments to the law of apples as necessary.

85. “All giraffes are beautiful and graceful. Gerald is a giraffe. Gerald is, therefore, beautiful and graceful.” According to the passage, this reasoning is a(an)

A) empirical verification.

B) induction from cases.

C) syllogism.

D) experimental conclusion.

86. A disease that is acquired by being exposed to other person’s who have the disease is thought by a physician to be caused by an infectious agent. This reasoning is an example of

A) the scientific method.

B) induction.

C) deduction.

D) hypothesis testing.

**Passage VII**

Consumers rely on several methods to acquire information about product quality. The most straightforward, of course, is to “experience” the product - eat it or use it. Low-priced, frequently purchased products require the experience approach, but some goods have “search” characteristics. Information on search goods can be obtained by inspection, asking one’s friends, or even reading technical reports.

Nelson has suggested advertising intensity as yet another index of product quality. Based largely on the experience and search characteristics and rational behavior by consumers, his theory is noteworthy in light of the widespread controversy over the information content of advertising.

Television advertising has often been criticized on the grounds that it lacks concrete product information. But Nelson finds fault with the criticisms. If advertising provides no information, then why do consumers respond to it? If there was truly no information provided, consumers would most likely learn to ignore or to be quite skeptical of the many commercials they see each day. Finally, only a relatively small proportion of products are heavily advertised. Apparently, there are many products for which advertising does not elicit strong consumer response.

Search product advertising is relatively non-controversial, since it provides “hard” information (such as price, location, brand, objective quality ratings, etc.) to consumers probably more cheaply than they can get it elsewhere. It can also be checked for accuracy before buying. It is advertising of experience goods that is often criticized for its lack of informational value and its effect on market performance.

Because such information may be misleading and consumers have no way of separating the truthful from the misleading, consumers have good reason not to respond to “informational” advertising about experience characteristics. Thus, there is less incentive for advertisers of experience goods to provide hard information beyond the product’s function. Do heavy expenditures on experience goods advertising provide any benefit to consumers if little accurate product information is conveyed? Nelson contends that they do. He says that heavy advertising is itself indirect information. Advertising is costly, and this cost may be incurred long before appreciable sales are made. Makers of heavily advertised, inferior products cannot expect repeated sales. Consumers will learn through experience that the brand is inferior. On the other hand, consumers who purchase a heavily advertised, superior product are likely to make further purchases as their experience reveals the product’s superiority. For that reason, Nelson argues that the makers of superior products can expect a greater return from advertising (more sales per unit of advertising) than can the makers of inferior products.

Producers of inferior products gain only initial purchases in response to advertising, while makers of superior products net initial plus repeat purchases. Since producers of superior products expect a higher return from their advertising, they have a greater incentive to advertise. If producers respond to this incentive, then superior products should be more heavily advertised than inferior, and consumers can with good reason use advertising as an indicator of product quality.

Nelson’s contention, that more heavily advertised products provide more quality for the price, is still quite controversial. It depends crucially on the ability of consumers to accurately assess product characteristics after purchase. His hypothesis is not concerned with characteristics whose quality cannot be determined even after use (for example, the efficacy of a drug). Nor is it concerned with the issue of whether advertising alters consumers’ perceptions. The validity of Nelson’s hypothesis is difficult to test.

Recently some preliminary tests of the hypothesis have been undertaken. Advertised brands in 11 different food product classes were selected for the test. Quality ratings of each brand were obtained from *Consumer Reports.* Sales and brands within each class were ranked according to their advertising expenditure per unit of sales. The research question was whether there was any tendency for brands ranked high in quality to also be ranked high in advertising per unit of sales. The results indicate a tendency for advertising intensity and quality to be positively associated in those samples. The coefficient was negative only for one product class.

The samples in this preliminary study are small, ranging from 5 to 12 brands in each product class; for that reason an inference that our estimates would hold for all brands in a product class is not justified. In addition, we are not testing Nelson’s strong contention that heavily advertised products provide more quality per dollar, but a weaker contention (held by most adherents to Nelson’s position) that heavily advertised products are of higher quality (without consideration of price).

Given the small sample size, we cannot say that the hypothesis is conclusively supported, nor can we make precise assertions about the strength of associations between advertising-sales ratios and product quality. However, Nelson’s hypothesis cannot be rejected on the basis of our data – he may be right and his theory deserves to be taken seriously. A key factor may be the extent to which consumers actually learn through experience.

87. The author’s purpose in writing this article is to

A) support Nelson’s theory.

B) oppose Nelson’s theory.

C) present and discuss some tests of Nelson’s theory.

D) present an alternative to Nelson’s theory.

88. The author’s tone is

A) skeptical.

B) intensive.

C) supportive.

D) scientific.

89. According to the passage, Nelson’s theory can be characterized by all of the following except that it is

A) hard to test in its strongest form.

B) based on rational decision-making by consumers.

C) opposed to the idea that television advertising has no informational content.

D) dependent on others for testing.

90. Which of the following future research findings would, if true, tend to weaken Nelson’s hypothesis?

I. New brands tend to be both heavily advertised and perceived as high quality.

II. Most non-search product advertising succeeds in blunting the consumer’s ability to evaluate the true quality of a product.

III. The reason many products are not advertised is that the response which is sure to be generated is hard to convert to profits for the advertiser when the product is not branded.

A) I only

B) II only

C) III only

D) I and III

91. Nelson’s hypothesis would apply to all of the following except

A) tomato soup.

B) caviar.

C) fish fillets.

D) milk.

92. The passage seems to

A) treat television advertising as the major part of advertising.

B) give too much weight to Nelson’s hypothesis.

C) be overly cautious in its interpretations.

D) confuse “experience” products with “search” products.

**STOP.** IF YOU FINISH BEFORE TIME IS CALLED, CHECK YOUR WORK. YOU MAY GO BACK TO ANY QUESTION IN THE VERBAL REASONING TEST BOOKLET.

**Writing Sample**

Time: 60 minutes total;

30 minutes per essay, each separately timed.

93. Essay Topic 1

**Politicians too often base their decisions on what will please the voters, not on what is best for the country.**

Write a unified essay in which you perform the following tasks. Explain what you think the above statement means. Describe a specific situation in which a politician might make an unpopular decision for the good of the country. Discuss the principles you think should determine whether political decisions should be made to please the voters or to serve the nation.

94. Essay Topic 2

**Justice is best served by truth.**

Write a unified essay in which you perform the following tasks. Explain what you think the above statement means. Describe a specific situation in which justice might not be served by truth. Discuss what you think determines whether or not truth serves justice.

**Content Outline for Physical Sciences Section of the MCAT**

**GENERAL CHEMISTRY**

**ELECTRONIC STRUCTURE AND PERIODIC TABLE**

1. **Electronic Structure** 
   1. Orbital structure of hydrogen atom, principal quantum number *n*, number of electrons per orbital
   2. Ground state, excited states
   3. Absorption and emission spectra
   4. Quantum numbers *l, m, s,* and number of electrons per orbital
   5. Common names and geometric shapes for orbitals *s, p, d*
   6. Conventional notation for electronic structure
   7. Bohr atom
   8. Effective nuclear charge
2. **The Periodic Table: Classification of Elements into Groups by Electronic Structure; Physical and Chemical Properties of Elements** 
   1. Alkali metals
   2. Alkaline earth metals
   3. Halogens
   4. Noble gases
   5. Transition metals
   6. Representative elements
   7. Metals and nonmetals
   8. Oxygen group
3. **The Periodic Table: Variations of Chemical Properties with Group and Row** 
   1. Electronic structure
      1. representative elements
      2. noble gases
      3. transition metals
   2. Valence electrons
   3. First and second ionization energies
      1. definition
      2. prediction from electronic structure for elements in different groups or rows
   4. Electron affinity
      1. definition
      2. variations with group and row
   5. Electronegativity
      1. definition
      2. comparative values for some representative elements and important groups
   6. Electron shells and the sizes of atoms

**BONDING**

1. **The Ionic Bond (Electrostatic Forces Between Ions)** 
   1. Electrostatic energy ** *q*1*q*2/*r*
   2. Electrostatic energy ** lattice energy
   3. Electrostatic force ** *q*1*q*2/*r2*
2. **The Covalent Bond** 
   1. Sigma and pi bonds
      1. hybrid orbitals (*sp*3, *sp*2, *sp*, and respective geometries)
      2. valence shell electron-pair repulsion (VSEPR) theory, predictions of shapes of molecules (e.g., NH3, H2O, CO2)
   2. Lewis electron dot formulas
      1. resonance structures
      2. formal charge
      3. Lewis acids and bases
   3. Partial ionic character
      1. role of electronegativity in determining charge distribution
      2. dipole moment

**PHASES AND PHASE EQUILIBRIA**

1. **Gas Phase** 
   1. Absolute temperature, K
   2. Pressure, simple mercury barometer
   3. Molar volume at 0°C and 1 atm = 22.4 L/mol
   4. Ideal gas
      1. definition
      2. ideal gas law (*PV = nRT*)
         1. Boyle’s law
         2. Charles’s law
         3. Avogadro’s law
   5. Kinetic theory of gases
   6. Deviation of real-gas behavior from ideal gas law
      1. qualitative
      2. quantitative (van der Waals equation)
   7. Partial pressure, mole fraction
   8. Dalton’s law relating partial pressure to composition

**B. Intermolecular Forces**

* 1. Hydrogen bonding
  2. Dipole interactions
  3. London dispersion forces

1. **Phase Equilibria** 
   1. Phase changes, phase diagrams
   2. Freezing point, melting point, boiling point, condensation point
   3. Molality
   4. Colligative properties
      1. vapor pressure lowering (Raoult’s law)
      2. boiling point elevation (Δ*T*b = Kb*m*)
      3. freezing point depression (Δ*T*f = Kf*m*)
      4. osmotic pressure
   5. Colloids
   6. Henry’s law

**STOICHIOMETRY**

1. Molecular weight
2. Empirical formula versus molecular formula
3. Metric units commonly used in the context of chemistry
4. Description of composition by percent mass
5. Mole concept, Avogadro’s number
6. Definition of density
7. Oxidation number
   1. common oxidizing and reducing agents
   2. disproportionation reactions
   3. redox titration
8. Description of reactions by chemical equations
   1. conventions for writing chemical equations
   2. balancing equations including redox equations
   3. limiting reactants
   4. theoretical yields

**THERMODYNAMICS AND THERMOCHEMISTRY**

1. **Energy Changes in Chemical Reactions: Thermochemistry** 
   1. Thermodynamic system, state function
   2. Endothermic and exothermic reactions
      1. enthalpy *H*, standard heats of reaction and formation
      2. Hess’s law of heat summation
   3. Bond dissociation energy as related to heats of formation
   4. Measurement of heat changes (calorimetry), heat capacity, specific heat capacity (specific heat capacity of water = 4.184 J/g·K)
   5. Entropy as a measure of “disorder,” relative entropy for gas, liquid, and crystal states
   6. Free energy *G*

7. Spontaneous reactions and *G*º

1. **Thermodynamics** 
   1. Zeroth law (concept of temperature)
   2. First law (Δ*E* = *q* + *w*, conservation of energy)
   3. Equivalence of mechanical, chemical, electrical, and thermal energy units
   4. Second law (concept of entropy)
   5. Temperature scales, conversions
   6. Heat transfer (conduction, convection, radiation)
   7. Heat of fusion, heat of vaporization
   8. *PV* diagram (work done = area under or enclosed by curve)

**RATE PROCESSES IN CHEMICAL REACTIONS: KINETICS AND EQUILIBRIUM**

1. Reaction rates
2. Rate law, dependence of reaction rate on concentrations of reactants
   1. rate constant
   2. reaction order
3. Rate-determining step
4. Dependence of reaction rate on temperature
   1. activation energy
      1. activated complex or transition state
      2. interpretation of energy profiles showing energies of reactants and products,

activation energy, *H* for the reaction

* 1. Arrhenius equation

1. Kinetic control versus thermodynamic control of a reaction
2. Catalysts, enzyme catalysis
3. Equilibrium in reversible chemical reactions
   1. law of mass action
   2. the equilibrium constant
   3. application of Le Châtelier’s principle

8. Relationship of the equilibrium constant and *G*º

**SOLUTION CHEMISTRY**

1. **Ions in Solution** 
   1. Anion, cation (common names, formulas, and charges for familiar ions; e.g., NH4+, ammonium; PO43–, phosphate; SO42–, sulfate)
   2. Hydration, the hydronium ion
2. **Solubility** 
   1. Units of concentration (e.g.,molarity)
   2. Solubility product constant, the equilibrium expression
   3. Common-ion effect, its use in laboratory separations
   4. Complex ion formation
   5. Complex ions and solubility
   6. Solubility and pH

**ACIDS AND BASES**

1. **Acid–Base Equilibria** 
   1. Brønsted–Lowry definition of acids and bases
   2. Ionization of water
      1. *K*w, its approximate value (*K*w= [H3O+][OH–] = 10–14at 25°C)
      2. pH definition, pH of pure water
   3. Conjugate acids and bases
   4. Strong acids and bases (common examples; e.g., nitric, sulfuric)
   5. Weak acids and bases (common examples; e.g., acetic, benzoic)
      1. dissociation of weak acids and bases with or without added salt
      2. hydrolysis of salts of weak acids or bases
      3. calculation of pH of solutions of weak acids or bases
   6. Equilibrium constants *K*a and *K*b (p*K*a and p*K*b)
   7. Buffers
      1. definition, concepts (common buffer systems)
      2. influence on titration curves
2. **Titration** 
   1. Indicators
   2. Neutralization
   3. Interpretation of titration curves

**ELECTROCHEMISTRY**

1. Electrolytic cell
   1. electrolysis
   2. anode, cathode
   3. electrolytes
   4. Faraday’s law relating amount of elements deposited (or gas liberated) at an electrode to current
   5. electron flow, oxidation and reduction at the electrodes
2. Galvanic (voltaic) cell
   1. half-reactions
   2. reduction potentials, cell potential
   3. direction of electron flow

**PHYSICS**

**TRANSLATIONAL MOTION**

1. Dimensions (length or distance, time)
2. Vectors, components
3. Vector addition
4. Speed, velocity (average and instantaneous)
5. Acceleration
6. Freely falling bodies

**FORCE AND MOTION, GRAVITATION**

1. Center of mass
2. Newton’s first law (inertia)
3. Newton’s second law (*F* = *ma*)
4. Newton’s third law (forces equal and opposite)
5. Concept of a field
6. Law of gravitation (*F* = –*Gm*1*m*2/*r*2)
7. Uniform circular motion
8. Centripetal force (*F* = –*mv*2/r)
9. Weight
10. Friction (static and kinetic)
11. Motion on an inclined plane
12. Analysis of pulley systems
13. Force

**EQUILIBRIUM AND MOMENTUM**

1. **Equilibrium** 
   1. Concept of force, units
   2. Translational equilibrium (  ***F****i* = 0)
   3. Rotational equilibrium (  *τ*i = 0)
   4. Analysis of forces acting on an object
   5. Newton’s first law (inertia)
   6. Torques, lever arms
   7. Weightlessness
2. **Momentum** 
   1. Momentum = *mv*
   2. Impulse = *Ft*
   3. Conservation of linear momentum
   4. Elastic collisions
   5. Inelastic collisions

**WORK AND ENERGY**

1. **Work** 
   1. Derived units, sign conventions
   2. Path independence of work done in gravitational field
   3. Mechanical advantage
   4. Work–energy theorem
   5. Power
2. **Energy** 
   1. Kinetic energy (KE = *mv*2/2, units)
   2. Potential energy
      1. gravitational, local (PE = *mgh*)
      2. spring (PE = *kx*2/2)
      3. gravitational, general (PE = –*GmM/r*)
   3. Conservation of energy
   4. Conservative forces
   5. Power, units

**WAVES AND PERIODIC MOTION**

1. **Periodic Motion** 
   1. Amplitude, period, frequency
   2. Phase
   3. Hooke’s law (*F* = –*kx*)
   4. Simple harmonic motion, displacement as a sinusoidal function of time
   5. Motion of a pendulum
   6. General periodic motion (velocity, amplitude)
2. **Wave Characteristics** 
   1. Transverse and longitudinal waves
   2. Wavelength, frequency, wave speed
   3. Amplitude and intensity
   4. Superposition of waves, interference, wave addition
   5. Resonance
   6. Standing waves (nodes, antinodes)
   7. Beat frequencies
   8. Refraction and general nature of diffraction

**SOUND**

1. Production of sound
2. Relative speed of sound in solids, liquids, and gases
3. Intensity of sound (decibel units, log scale)
4. Attenuation
5. Doppler effect (moving sound source or observer, reflection of sound from a moving object)
6. Pitch
7. Resonance in pipes and strings
8. Harmonics
9. Ultrasound

**FLUIDS AND SOLIDS**

1. **Fluids** 
   1. Density, specific gravity
   2. Archimedes’ principle (buoyancy)
   3. Hydrostatic pressure
      1. Pascal’s law
      2. pressure versus depth (*P* = ρ*gh*)
   4. Poiseuille flow (viscosity)
   5. Continuity equation (*Av* = constant)
   6. Concept of turbulence at high velocities
   7. Surface tension
   8. Bernoulli’s equation
2. **Solids** 
   1. Density
   2. Elastic properties (elementary properties)
   3. Elastic limit
   4. Thermal expansion coefficient
   5. Shear
   6. Compression

**ELECTROSTATICS AND ELECTROMAGNETISM**

1. **Electrostatics** 
   1. Charges, conductors, charge conservation
   2. Insulators
   3. Coulomb’s law (*F* = *kq*1*q*2/*r*2, sign conventions)
   4. Electric field
      1. field lines
      2. field due to charge distribution
   5. Potential difference, absolute potential at point in space
   6. Equipotential lines
   7. Electric dipole
      1. definition of dipole
      2. behavior in electric field
      3. potential due to dipole
   8. Electrostatic induction
   9. Gauss’s law
2. **Magnetism** 
   1. Definition of the magnetic field **B**
   2. Existence and direction of force on charge moving in magnetic field
3. **Electromagnetic Radiation (Light)** 
   1. Properties of electromagnetic radiation (general properties only)
      1. radiation velocity equals constant *c* in vacuo
      2. radiation consists of oscillating electric and magnetic fields that are mutually perpendicular to each other and to the propagation direction
   2. Classification of electromagnetic spectrum (radio, infrared, UV, X-rays, etc.)

**ELECTRONIC CIRCUIT ELEMENTS**

1. **Circuit Elements** 
   1. Current (*I* = *Q*/Δ*t*, sign conventions, units)
   2. Battery, electromotive force, voltage
   3. Terminal potential, internal resistance of battery
   4. Resistance
      1. Ohm’s law (*I* = *V*/*R*)
      2. resistors in series
      3. resistors in parallel
      4. resistivity (*ρ* = *RA*/*L*)
   5. Capacitance
      1. concept of parallel-plate capacitor
      2. energy of charged capacitor
      3. capacitors in series
      4. capacitors in parallel
      5. dielectrics
   6. Discharge of a capacitor through a resistor
   7. Conductivity theory
2. **Circuits** 
   1. Power in circuits (*P* = *VI, P* = *I*2*R*)
3. **Alternating Currents and Reactive Circuits** 
   1. Root-mean-square current
   2. Root-mean-square voltage

**LIGHT AND GEOMETRICAL OPTICS**

1. **Light (Electromagnetic Radiation)**

1. Concept of interference, Young’s double-slit experiment

* 1. Thin films, diffraction grating, single-slit diffraction
  2. Other diffraction phenomena, X-ray diffraction
  3. Polarization of light
  4. Doppler effect (moving light source or observer)
  5. Visual spectrum, color
     1. energy
     2. lasers

1. **Geometrical Optics** 
   1. Reflection from plane surface (angle of incidence equals angle of reflection)
   2. Refraction, refractive index *n*, Snell’s law (*n*1sin** 1 = *n*2sin** 2)
   3. Dispersion (change of index of refraction with wavelength)
   4. Conditions for total internal reflection
   5. Spherical mirrors
      1. mirror curvature, radius, focal length
      2. use of formula (1/*p*) + (1/*q*) = 1/*f* with sign conventions
      3. real and virtual images
   6. Thin lenses
      1. converging and diverging lenses, focal length
      2. use of formula (1/*p*) + (1/*q*) = 1/*f* with sign conventions
      3. real and virtual images
      4. lens strength, diopters
      5. lens aberration
   7. Combination of lenses
   8. Ray tracing
   9. Optical instruments

**ATOMIC AND NUCLEAR STRUCTURE**

1. **Atomic Structure and Spectra** 
   1. Emission spectrum of hydrogen (Bohr model)
   2. Atomic energy levels
      1. quantized energy levels for electrons
      2. calculation of energy emitted or absorbed when an electron changes energy levels
2. **Atomic Nucleus** 
   1. Atomic number, atomic weight
   2. Neutrons, protons, isotopes
   3. Nuclear forces
   4. Radioactive decay (α, β, γ, half-life, stability, exponential decay, semilog plots)
   5. General nature of fission
   6. General nature of fusion
   7. Mass deficit, energy liberated, binding energy