UNIVERSITY OF SWAZILAND

FINAL EXAMINATION – 2014, MAY

TITLE OF PAPER : Introductory Chemistry II

COURSE NUMBER : C112

TIME : Three Hours

INSTRUCTIONS :

1. **Answer all questions in Section A** (Total 50 marks)
2. **Answer any two questions in Section B** (each question is 25 marks)

NB: Non-programmable electronic calculators may be used

A data sheet, a periodic table and answer sheet (for **Section A**) are attached

Useful data and equations:

1 atm = 760 Torr = 760 mmHg

1 atm = 101325 Pa

Arrhenius equation: $k = Ae^{-E_a/RT}$ or $lnk = lnA - \frac{E_a}{RT}$

Van der Walls equation: $P = \frac{nRT}{V-nb} - \frac{n^2a}{V^2}$

This Examination Paper Contains Six Printed Pages Including This Page

You are not supposed to open the paper until permission to do so has been granted by the Chief Invigilator.

Section A

1. Which of the following is/are characteristic(s) of gases?

   A. High compressibility
   B. Relatively large distances between molecules
   C. Formation of homogeneous mixtures regardless of the nature of gases
   D. High compressibility AND relatively large distances between molecules
   E. High compressibility, relatively large distances between molecules AND formation of homogeneous mixtures regardless of the nature of gases

2. A sample of a gas occupies 1.40×10^3 mL at 25°C and 760 mmHg. What volume will it occupy at the same temperature and 380 mmHg?
   A. 2,800 mL
   B. 2,100 mL
   C. 1,400 mL
   D. 1,050 mL
   E. 700 mL

3. A sample of nitrogen gas has a volume of 32.4 L at 20°C. The gas is heated to 220°C at constant pressure. What is the final volume of nitrogen?
   A. 2.94 L
   B. 19.3 L
   C. 31.4 L
   D. 54.5 L
   E. 356 L

4. A sample of N_2 gas occupies 2.40 L at 20°C. If the gas is in a container that can contract or expand at constant pressure, at what temperature will the N_2 occupy 4.80 L?
   A. 10°C
   B. 40°C
   C. 146°C
   D. 313°C
   E. 685°C

5. The gas pressure in an aerosol can is 1.8 atm at 25°C. If the gas is an ideal gas, what pressure would develop in the can if it were heated to 475°C?
   A. 0.095 atm
   B. 0.717 atm
   C. 3.26 atm
   D. 4.52 atm
   E. 34.2 atm

6. A small bubble rises from the bottom of a lake, where the temperature and pressure are 4°C and 3.0 atm, to the water's surface, where the temperature is 25°C and the pressure is 0.95 atm. Calculate the final volume of the bubble if its initial volume was 2.1 mL.
   A. 0.72 mL
   B. 6.2 mL
   C. 41.4 mL
   D. 22.4 mL
   E. 7.1 mL

7. 0.820 mole of hydrogen gas has a volume of 2.00 L at a certain temperature and pressure. What is the volume of 0.125 mol of this gas at the same temperature and pressure?
   A. 0.0512 L
   B. 0.250 L
   C. 0.305 L
   D. 4.01 L
   E. 19.5 L

8. At what temperature will a fixed mass of gas with a volume of 125 L at 15°C and 750 mmHg occupy a volume of 101 L at a pressure of 645 mm Hg?

A. -73°C
B. 10.4°C
C. 2°C
D. 34°C
E. 200°C

9. A gas evolved during the fermentation of sugar was collected at 22.5°C and 702 mmHg. After purification its volume was found to be 25.0 L. How many moles of gas were collected?

A. 0.95 mol
B. 1.05 mol
C. 12.5 mol
D. 22.4 mol
E. 724 mol

10 Calculate the mass, in grams, of 2.74 L of CO gas measured at 33°C and 945 mmHg.

A. 0.263 g
B. 2.46 g
C. 3.80 g
D. 35.2 g
E. 206 g

11. At equilibrium, __________.

A) All chemical reactions have ceased
B) The rates of the forward and reverse reactions are equal
C) The rate constants of the forward and reverse reactions are equal
D) The value of the equilibrium constant is 1
E) The limiting reagent has been consumed

12. Which of the following expressions is the correct equilibrium-constant expression for the following reaction?

$CO_2\ (g) + 2H_2\ (g) \longrightarrow CH_3OH\ (g)$

A) $\frac{[CH_3OH]}{[CO_2]}$

B) $\frac{[CH_3OH]}{[CO_2][H_2]}$

C) $\frac{[CO_2][H_2]^2}{[CH_3OH]}$

D) $\frac{[CO_2][H_2]}{[CH_3OH]}$

E) $\frac{[CH_3OH]}{[CO_2][H_2]^2}$

13. A sample of NOBr (0.64 mol) was placed in a 1.00-L flask containing no NO or Br_2. At equilibrium the flask contained 0.36 mol of NOBr. How many moles of NO and Br_2, respectively, are in the flask at equilibrium?

A) .28,.28
B) .36,.18
C) .28,.14
D) .14,.23
E) .36,.36

14. K_p = 0.0198 at 721 K for the reaction

$2HI\ (g) \longrightarrow H_2\ (g) + I_2\ (g)$

In a particular experiment, the partial pressures of H_2 and I_2 at equilibrium are 0.836 and 0.701 atm, respectively. The partial pressure of HI is __________ atm.

A) 7.87
B) 29.6
C) 5.44
D) 0.108
E) 0.0116

15. Which one of the following will change the value of an equilibrium constant?

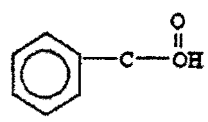
A) changing temperature
B) adding other substances that do not react with any of the species involved in the equilibrium
C) varying the initial concentrations of reactants
D) varying the initial concentrations of products
E) changing the volume of the reaction vessel

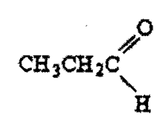
16. The equilibrium-constant expression depends on the __________ of the reaction.

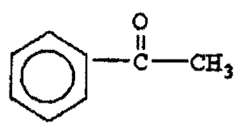
A) stoichiometry
B) mechanism
C) stoichiometry and mechanism
D) the quantities of reactants and products initially present
E) temperature

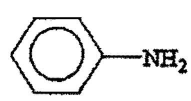
17. Which structure below represents an amine?

A) $CH_3CH_2 — O — CH_2CH_3$

B) 

C) 

D) 

E) 

18. Consider the following two reactions:

$A \rightarrow 2B$ ΔH°_{rxn} = 456.7 kJ/mol

$A \rightarrow C$ ΔH°_{rxn} = -22.1kJ/mol

Determine the enthalpy change for the process:

$2B \rightarrow C$

A) -478.8 kJ/mol
B) -434.6 kJ/mol
C) 434.6 kJ/mol
D) 478.8 kJ/mol
E) More information is needed to solve the problem.

19. The kinetic-molecular theory predicts that pressure rises as the temperature of a gas increases because __________.

A) The average kinetic energy of the gas molecules decreases
B) The gas molecules collide more frequently with the wall
C) The gas molecules collide less frequently with the wall
D) The gas molecules collide more energetically with the wall
E) Both the gas molecules collide more frequently with the wall and the gas molecules collide more energetically with the wall

20. Identify the **INCORRECT** statement below:

a) Potential energy is the energy possessed by virtue of position or composition.
b) Energy is the capacity to do work or transfer heat.

c) In an exothermic reaction the value of H of the species is increasing in going from reactants to products.

d) Energy is neither created or destroyed in ordinary chemical reactions.

e) Kinetic energy is the energy of motion.

21. 1) A burning splint will burn more vigorously in pure oxygen than in air because

A) oxygen is a reactant in combustion and concentration of oxygen is higher in pure oxygen than is in air.

B) oxygen is a catalyst for combustion.

C) oxygen is a product of combustion.

D) nitrogen is a product of combustion and the system reaches equilibrium at a lower temperature.

E) nitrogen is a reactant in combustion and its low concentration in pure oxygen catalyzes the combustion.

22. Which one of the following is <u>not</u> a valid expression for the rate of the reaction below?

$4NH_3 + 7O_2 \rightarrow 4NO_2 + 6H_2O$

A) $-\frac{1}{7}\frac{\Delta[O_2]}{\Delta t}$

B) $\frac{1}{4}\frac{\Delta[NO_2]}{\Delta t}$

C) $\frac{1}{6}\frac{\Delta[H_2O]}{\Delta t}$

D) $-\frac{1}{4}\frac{\Delta[NH_3]}{\Delta t}$

E) All of the above are valid expressions of the reaction rate.

23. Which statement is **INCORRECT**?

a) A process that absorbs energy from its surroundings is called endothermic.

b) In an exothermic reaction the enthalpy of species increases.

c) Energy is the capacity to do work or to transfer heat.

d) Kinetic energy is the energy of motion.

e) Potential energy is the energy that a system possesses by virtue of its position or composition.

24. 7) How many isomers are possible for C_4H_{10}?

A) 1

B) 2

C) 3

D) 4

E) 10

25. How much heat is absorbed in the complete reaction of 3.00 grams of SiO_2 with excess carbon in the reaction below? $\Delta H°$ for the reaction as written is +624.7 kJ.

$SiO_2(g) + 3\ C(s) \rightarrow SiC(s) + 2\ CO(g)$

a) 31.2 kJ

b) 1.13×10^5 kJ

c) 5.06 kJ

d) 1.33×10^4 kJ

e) 366 kJ

26. Which statement about hydrocarbons is <u>false</u>?

A) The smallest alkane to have structural (constitutional) isomers has 4 carbon atoms.

B) Cyclic alkanes are structural isomers of alkenes.

C) Alkanes are more reactive than alkenes.
D) Alkanes can be produced by hydrogenating alkenes.
E) Alkenes can be polymerized.

27. From the following data at 25°C:
$H_2(g) + Cl_2 \longrightarrow 2\ HCl(g)$; $\Delta H° = -185$ kJ
$2\ H_2(g) + O_2(g) \longrightarrow 2\ H_2O(g)$; $\Delta H° = -483.7$ kJ
Calculate ΔH° at 25° for the reaction below:
$4\ HCl(g) + O_2(g) \longrightarrow 2\ Cl_2(g) + 2\ H_2O(g)$
a) +114 kJ
b) +299 kJ
c) -299 kJ
d) -114 kJ
e) -86.8 kJ

28. Given the standard heats of formation for the following compounds, calculate the ΔH° heat of reaction, for the following reaction:
$Fe_3O_4(s) + CO(g) \longrightarrow 3\ FeO(s) + CO_2(g)$
$\Delta H_f°$ for Fe_3O_4 = -1118 kJ
$\Delta H_f°$ for CO = -110.5 kJ
$\Delta H_f°$ for FeO = -272 kJ
$\Delta H_f°$ for CO_2= -393.5 kJ
a) 54 kJ
b) 19 kJ
c) -263 kJ
d) -50 kJ
e) 109 kJ

29. Benzene behaves differently from a hydrocarbon which simply contains three C=C bonds in that the latter would be expected to react much more readily with __________.
A) H_2
B) Cl_2
C) Br_2
D) HCl
E) all of the above

30. A particular chemical reaction is characterized by ΔH_{rxn} = +250 kJ/mol. Which of the following statements are true concerning this reaction?
I. Heat is liberated to the surroundings.
II. The reaction is endothermic.
III. The heat content of the products are lower than the reactants.
a) all are true
b) only II and III are true
c) only I and II are true
d) only II is true
e) none are true

31. Which one of the following is not an alcohol?
A) acetone
B) glycerol
C) ethanol
D) cholesterol
E) ethylene glycol

32. The following reaction would produce a(n) __________.
$R\text{-}OH + R'COOH \longrightarrow ?$
A) ketone

B) ether
C) aldehyde
D) alcohol
E) ester

33. From the following enthalpies of reaction find ΔH_{rxn} for
$2\ HCl(g) + F_2(g) \longrightarrow 2\ HF(l) + Cl_2(g)$:
$4\ HCl(g) + O_2(g) \text{--->} 2\ H_2O(l) + 2\ Cl_2(g)$; $\Delta H = -148.4$ kJ/mol
$1/2\ H_2(g) + 1/2\ F_2(g) \text{--->} HF(l)$; $\Delta H = -600.0$ kJ/mol
$H_2(g) + 1/2\ O_2(g) \text{--->} H_2O(l)$; $\Delta H = -285.8$ kJ/mol
a) +766 kJ/mol
b) -988 kJ/mol
c) -840 kJ/mol
d) +1337 kJ/mol
e) -1560 kJ/mol

34. A reaction of 0.25 grams of CaO(s) with excess HCl(aq) results in a temperature rise of 1.23°C. The calorimeter solution is found before hand to have a heat capacity of 96 cal/°C. What is the ΔH_{rxn} per mole of the following reaction?
$CaO(s) + 2\ HCl \longrightarrow CaCl_2(aq) + H_2O(l)$
a) -26.4 kcal/mol
b) -474.8 kcal/mol
c) +474.8 kcal/mol
d) 26600 kcal/mol
e) -56 kcal/mol

35. Which of the following compounds do not contain an sp^3 hybridized oxygen atom?
A) ketones
B) alcohols
C) ethers
D) esters
E) water

36. Calculate ΔH_f for HCN(g) at 25°C, given the following related reaction at 25°C,
$2\ NH_3(g) + 3\ O_2(g) + 2\ CH_4(g) \text{--->} 2\ HCN(g) + 6\ H_2O(g)$; $\Delta H_{rxn} = -870.8$ kJ
and the heats of formation of some species are $\Delta H_f = -80.3$ kJ/mol for $NH_3(g)$, -74.6 kJ/mol for CH_4, and -241.8 kJ/mol for $H_2O(g)$. Answers are in kJ/mol.
a) -135
b) -147
c) +270
d) +135
e) -870.8

37. Calculate ΔH° at 25°C for the reaction $4\ HCl(g) + O_2(g) \text{--->} 2\ Cl_2(g) + 2\ H_2O(g)$ from the following data:
$H_2(g) + Cl_2(g) \text{--->} 2\ HCl(g)$; $\Delta H^\circ = -185$ kJ at 25°C
$2\ H_2(g) + O_2(g) \text{--->} 2\ H_2O(g)$; $\Delta H^\circ = -483.7$ kJ at 25°C
a) -299 kJ
b) -86.8 kJ
c) +299 kJ
d) +114 kJ
e) -114 kJ

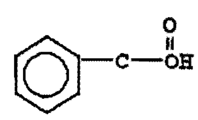
38. How much heat is released when 75 g of octane is burned completely if the enthalpy of combustion is -5,500 kJ/mol C_8H_{18}? The reaction is
$C_8H_{18} + 25/2\ O_2 \longrightarrow 8\ CO_2 + 9\ H_2O$.

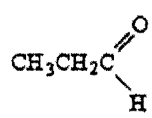
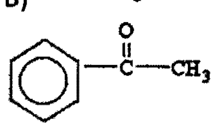
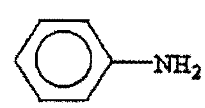
a) 4.1×10^5 kJ
b) 3600 kJ
c) 7200 kJ
d) 8360 kJ
e) 5500 kJ

39. If 4.168 kJ of heat is added to a calorimeter containing 75.40 g of water, the temperature of the water and the calorimeter increases from 24.58°C to 35.82°C. Calculate the heat capacity of the calorimeter (in J/°C). The specific heat of water is 4.184 J/g °C.
a) 25.31 J/°C
b) 17.36 J/°C
c) 55.34 J/°C
d) 315.5 J/°C
e) 622 J/°C

40. Estimate the enthalpy change for the reaction below (in kJ/mol) from the average bond energies given. There are two C-Cl and two C-H bonds in CH_2Cl_2. Remember that energy is absorbed when bonds are broken and released when they are formed.
$CH_4(g) + 2\ Cl_2(g) \dashrightarrow CH_2Cl_2(g) + 2\ HCl(g)$
Average Bond Energies
C-H = 413 kJ/mol
H-Cl = 432 kJ/mol
Cl-Cl = 242 kJ/mol
C-Cl = 339 kJ/mol
a) +232
b) -578
c) -232
d) +578
e) +541

41. Which structure below is not correctly drawn?

A) CH_3CH_2 — O — CH_2CH_3 B) 

C)  D)  E) 

42. Calculate ΔH° at 25°C for the reaction below given the heats of formation.
$2\ ZnS(s) + 3\ O_2(g) \longrightarrow 2\ ZnO(s) + 2\ SO_2(g)$
ΔH_f (kJ/mol) for 2 ZnS(s) = -205.6
ΔH_f (kJ/mol) for 3 O_2(g) = 0
Δ>H_f (kJ/mol) for 2 ZnO(s) = -348.3
ΔH_f (kJ/mol) for 2 SO_2(g) = -296.8
a) -582.2 kJ
b) -879.0 kJ
c) +257.1 kJ
d) +879.0 kJ
e) -257.1 kJ

43. Hybridization of the carbon atom indicated by (*) in CH_3-* CH_2- CH_3, *CH_2=CH_2, and CH_3-*C≡CH is __________, __________, and __________, respectively.
A) sp^3, sp^2, sp
B) sp^3, sp, sp^2
C) sp, sp^2, sp^3

D) sp, sp^3, sp^2

E) sp^2, sp^3, sp

44. The name of CH_3-CH=C=CH-CH-CH=CH-CH_3 is __________.

A) 2, 3, 5 - octatriene
B) 2, 5, 6 - octatriene
C) 2, 3, 6 - octatriene
D) 3, 5, 6 - octatriene
E) 3, 4, 7 - octatriene

45. __________ could be the formula of an alkene.

A) C_3H_8
B) C_3H_6
C) C_6H_6
D) $C_{17}H_{36}$
E) CH_8

46. The addition of HBr to 2-butene produces __________.

A) 1-bromobutane
B) 2-bromobutane
C) 1,2-dibromobutane
D) 2,3-dibromobutane
E) no reaction

The data in the table below were obtained for the reaction:

$2\ ClO_2\ (aq) + 2\ OH^-\ (aq) \rightarrow ClO_3^-\ (aq) + ClO_2^-\ (aq) + H_2O\ (l)$

Experiment Number	$[ClO_2]$ (M)	$[OH^-]$ (M)	Initial Rate (M/s)
1	0.060	0.030	0.0248
2	0.020	0.030	0.00276
3	0.020	0.090	0.00828

47. What is the order of the reaction with respect to ClO_2?

A) 1
B) 0
C) 2
D) 3
E) 4

48. What is the order of the reaction with respect to OH^-?

A) 0
B) 1
C) 2
D) 3
E) 4

49. What is the overall order of the reaction?

A) 4
B) 0
C) 1
D) 2
E) 3

50. What is the magnitude of the rate constant for the reaction?

A) 1.15×10^4
B) 4.6
C) 230
D) 115
E) 713

Section B

Question 1

a. Write the equilibrium-constant expression K_c for

i. $H_2(g) + I_2(g) \rightleftharpoons 2\,HI(g)$ (2)

ii. $Cd^{2+}(aq) + 4\,Br^-(aq) \rightleftharpoons CdBr_4^{2-}(aq)$ (2)

b. The initial rate of a reaction A + B → C was measured for several different starting concentrations of A and B, and the results are as follows:

Experiment Number	[A] (*M*)	[B] (*M*)	Initial Rate (*M*/s)
1	0.100	0.100	4.0×10^{-5}
2	0.100	0.200	4.0×10^{-5}
3	0.200	0.100	16.0×10^{-5}

Using these data, determine (6)

i. the rate law for the reaction,

ii. the rate constant,

iii. the rate of the reaction, when [A] = 0.050 *M* and [B] = 0.100 *M*.

c. What is the conjugate acid of CN^-, SO_4^{2-}, H_2O, HCO_3^-? (2)

d. Calculate the concentration of H^+ (*aq*) in

i. a solution in which $[OH^-]$ is 0.010 *M*,

ii. a solution in which $[OH^-]$ is 1.8×10^{-9} *M* both at 25 °C. (4)

e. The hydrogen sulfite ion (HSO_3^-) is amphiprotic. Write an equation for the reaction of HSO_3^- with water

i. in which the ion acts as an acid and (2)

ii. in which the ion acts as a base. In both cases identify the conjugate acid–base pairs (2)

f. In the coal-gasification process, carbon monoxide is converted to carbon dioxide via the following reaction:

$CO(g) + H_2O(g) \longrightarrow CO_2(g) + H_2(g)$

In an experiment, 0.35 mol of CO and 0.40 mol of H_2O were placed in a 1.00 L reaction vessel. At equilibrium, there were 0.19 mol of CO remaining. Calculate K_{eq} at the temperature (5)

Question 2

a. Name any six classes of organic compounds. (3)

b. Give the functional group and a named example for each of the classes of compounds named above. (9)

c. Is a C_3H_6 a saturated hydrocarbon or not? Explain your answer. (1)

d. Draw all the structural and geometric isomers of pentene, C_6H_{10}, that have an unbranched hydrocarbon chain. (4)

e. Beer was brewed by ancient Egyptians and is thought to have been of the rations of the builders of pyramids. The energy content of beer comes from glucose and ethanol. The glucose and ethanol composition of beer is given below:

Constituent	Concentration (g/dm^3)
Ethanol, C_2H_5OH	20
Glucose, $C_6H_{12}O_6$	20

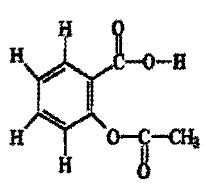
Ethanol is food as well as a drug. Like glucose it burns to give carbon dioxide and water.

i) Write balanced equations for the complete combustion of ethanol and glucose (2)

ii) Given that the standard enthalpy change of combustion for ethanol and glucose are -1370 kJ mol^{-1} and -3000 kJ mol^{-1} respectively, calculate the enthalpy change per gram for both glucose and ethanol. (6)

Question 3

a. A BSc student dissolves an asprin tablet in 0.500 L of water at 25°C. the tablet is known to contain 0.32 g of acetylsalicylic acid, $HC_9H_7O_4$ whose structure is given below:



acetylsalicyclic acid

i) Write the equilibrium expression for the ionization of acetylsalicyclic acid in water (2)

ii) Given that Ka = 3.3 x 10-4 for acetylsalicyclic acid at 25°C, calculate the pH of the asprin solution. (5)

b. With reasons, state which direction will each of the following reactions shift after the specified stress is applied.

i) $N_2O_4(g) \longrightarrow 2NO_2(g)$

(an increase in total pressure) (2)

ii) $2Cl_2(g) + 2H_2O(l) \longrightarrow 4HCl(g) + O_2(g)$ $\Delta H° = -113kJ$

(a decrease in temperature) (2)

iii) $CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$

(removal of some of the CO_2 formed) (2)

c. Define or explain the following terms:

i) Calorimeter constant (2)

ii) Enthalpy change of combustion, ΔH°_c (2)

iii) Enthalpy change of vaporization, ΔH°_{vap} (2)

d. When a reaction that was known to release 35.10 kJ of heat was carried out in a bomb calorimeter containing 100 mL of water, a 7.3°C rise in temperature was observed. A small amount of salt was placed in the same calorimeter and 100.0 mL of dilute HCL(aq) was added to it. The temperature then rose by 3.25°C. Calculated the heat released during this reaction. (6)

UNIVERSITY OF SWAZILAND

C112 SECTION A ANSWER SHEET

STUDENT ID NUMBER:______________________

The correct answer must be indicated by putting a circle around the letter for that answer on the answer sheet provided below. If you change your answer, please cancel the wrong answer with a cross and then put a circle around the correct one. If more than one option has a circle around it, a zero will be given for that question.

	A	B	C	D	E		A	B	C	D	E
1						**26**					
2						**27**					
3						**28**					
4						**29**					
5						**30**					
6						**31**					
7						**32**					
8						**33**					
9						**34**					
10						**35**					
11						**36**					
12						**37**					
13						**38**					
14						**39**					
15						**40**					
16						**41**					
17						**42**					
18						**43**					
19						**44**					
20						**45**					
21						**46**					
22						**47**					
23						**48**					
24						**49**					
25						**50**					

General data and fundamental constants

Quantity	Symbol	Value
Speed of light	c	$2.997\ 924\ 58 \times 10^{8}$ m s^{-1}
Elementary charge	e	$1.602\ 177 \times 10^{-19}$ C
Faraday constant	$F = N_A e$	9.6485×10^{4} C mol^{-1}
Boltzmann constant	k	$1.380\ 66 \times 10^{-23}$ J K^{-1}
Gas constant	$R = N_A k$	$8.314\ 51$ J K^{-1} mol^{-1}
		$8.205\ 78 \times 10^{-2}$ dm^{3} atm K^{-1} mol^{-1}
		6.2364×10 L Torr K^{-1} mol^{-1}
Planck constant	h	$6.626\ 08 \times 10^{-34}$ J s
	$\hbar = h/2\pi$	$1.054\ 57 \times 10^{-34}$ J s
Avogadro constant	N_A	$6.022\ 14 \times 10^{23}$ mol^{-1}
Atomic mass unit	u	$1.660\ 54 \times 10^{-27}$ Kg
Mass		
electron	m_e	$9.109\ 39 \times 10^{-31}$ Kg
proton	m_p	$1.672\ 62 \times 10^{-27}$ Kg
neutron	m_n	$1.674\ 93 \times 10^{-27}$ Kg
Vacuum permittivity	$\varepsilon_0 = 1/c^2\mu_0$	$8.854\ 19 \times 10^{-12}$ J^{-1} C^{2} m^{-1}
	$4\pi\varepsilon_0$	$1.112\ 65 \times 10^{-10}$ J^{-1} C^{2} m^{-1}
Vacuum permeability	μ_0	$4\pi \times 10^{-7}$ J s^{2} C^{-2} m^{-1}
		$4\pi \times 10^{-7}$ T^{2} J^{-1} m^{3}
Magneton		
Bohr	$\mu_B = e\hbar/2m_e$	$9.274\ 02 \times 10^{-24}$ J T^{-1}
nuclear	$\mu_N = e\hbar/2m_p$	$5.050\ 79 \times 10^{-27}$ J T^{-1}
g value	g_e	$2.002\ 32$
Bohr radius	$a_0 = 4\pi\varepsilon_0\hbar/m_e e^2$	$5.291\ 77 \times 10^{-11}$ m
Fine-structure constant	$\alpha = \mu_0 e^2 c/2h$	$7.297\ 35 \times 10^{-3}$
Rydberg constant	$R_\infty = m_e e^4/8h^3 c\varepsilon_0^2$	$1.097\ 37 \times 10^{7}$ m^{-1}
Standard acceleration of free fall	g	$9.806\ 65$ m s^{-2}
Gravitational constant	G	$6.672\ 59 \times 10^{-11}$ N m^{2} Kg^{-2}

Conversion factors

1 cal	=	4.184 joules (J)	1 erg	=	1×10^{-7} J
1 eV	=	$1.602\ 2 \times 10^{-19}$ J	1 eV/molecule	=	96 485 kJ mol^{-1}

Prefixes

f	p	n	μ	m	c	d	k	M	G
femto	pico	nano	micro	milli	centi	deci	kilo	mega	giga
10^{-15}	10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^{-2}	10^{-1}	10^{3}	10^{6}	10^{9}

PERIODIC TABLE OF ELEMENTS

Atomic mass → / Symbol → / Atomic No. →

	GROUPS																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
PERIODS	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1	1.008 H 1																	4.003 He 2
2	6.941 Li 3	9.012 Be 4											10.811 B 5	12.011 C 6	14.007 N 7	15.999 O 8	18.998 F 9	20.180 Ne 10
3	22.990 Na 11	24.305 Mg 12	TRANSITION ELEMENTS										26.982 Al 13	28.086 Si 14	30.974 P 15	32.06 S 16	35.453 Cl 17	39.948 Ar 18
4	39.098 K 19	40.078 Ca 20	44.956 Sc 21	47.88 Ti 22	50.942 V 23	51.996 Cr 24	54.938 Mn 25	55.847 Fe 26	58.933 Co 27	58.69 Ni 28	63.546 Cu 29	65.39 Zn 30	69.723 Ga 31	72.61 Ge 32	74.922 As 33	78.96 Se 34	79.904 Br 35	83.80 Kr 36
5	85.468 Rb 37	87.62 Sr 38	88.906 Y 39	91.224 Zr 40	92.906 Nb 41	95.94 Mo 42	98.907 Tc 43	101.07 Ru 44	102.91 Rh 45	106.42 Pd 46	107.87 Ag 47	112.41 Cd 48	114.82 In 49	118.71 Sn 50	121.75 Sb 51	127.60 Te 52	126.90 I 53	131.29 Xe 54
6	132.91 Cs 55	137.33 Ba 56	138.91 *La 57	178.49 Hf 72	180.95 Ta 73	183.85 W 74	186.21 Re 75	190.2 Os 76	192.22 Ir 77	195.08 Pt 78	196.97 Au 79	200.59 Hg 80	204.38 Tl 81	207.2 Pb 82	208.98 Bi 83	(209) Po 84	(210) At 85	(222) Rn 86
7	223 Fr 87	226.03 Ra 88	(227) **Ac 89	(261) Rf 104	(262) Ha 105	(263) Unh 106	(262) Uns 107	(265) Uno 108	(266) Une 109	(267) Uun 110								

*Lanthanide Series	140.12 Ce 58	140.91 Pr 59	144.24 Nd 60	(145) Pm 61	150.36 Sm 62	151.96 Eu 63	157.25 Gd 64	158.93 Tb 65	162.50 Dy 66	164.93 Ho 67	167.26 Er 68	168.93 Tm 69	173.04 Yb 70	174.97 Lu 71
**Actinide Series	232.04 Th 90	231.04 Pa 91	238.03 U 92	237.05 Np 93	(244) Pu 94	(243) Am 95	(247) Cm 96	(247) Bk 97	(251) Cf 98	(252) Es 99	(257) Fm 100	(258) Md 101	(259) No 102	(260) Lr 103

( ) indicates the mass number of the isotope with the longest half-life.