FOUNDATION YEAR FOUN10001
Inorganic and Part I of Physical Chemistry

Tutorial booklet

Contents

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CHEMISTRY 1 Tutorial 00

The mole concept

1. Calculate the mass, in kg, of one atom of ^{49}Ti

2. A sample of C_3H_8 has 4.64×10^{24} H atoms. (a) How many carbon atoms does this sample contain? (b) What is the total mass of the sample?

3. A single electron has the mass $9.10938356 \times 10^{-28}$ g. Calculate the mass, in kg, of the electrons in one mole of carbon.

4. 6.80 g of sodium chloride are added to 2750 cm^3 of water. What is the concentration of the solution in $mol.dm^{-3}$

5. Calculate the mass of magnesium chloride needed to make 250 cm^3 of a 0.075 M solution

6. Calculate the volume of a 0.75 M solution that contains 33g of potassium hydroxide

7. In the extraction of titanium, titanium(IV) chloride reacts with magnesium to form magnesium chloride and titanium. Calculate the maximum mass of titanium that can be extracted from 1kg of titanium chloride reacting with 250g of magnesium.

8. 20.0 cm^3 of a solution of barium hydroxide, $Ba(OH)_2$, of unknown concentration is placed in a conical flask and titrated with a solution of hydrochloric acid which has a concentration of 0.0600 $mol.dm^{-3}$. The volume-of acid required is 25.0 cm^3. Calculate the concentration of the barium hydroxide solution.

9. In the screaming jelly baby reaction, glucose is oxidised by potassium chlorate according to the following equation.

$$C_6H_{12}O_6 + 4KClO_3 \rightarrow 6CO_2 + 6H_2O + 4KCl$$

(a) Calculate the mass of potassium chlorate needed to completely oxidise 1g of glucose.

(b) Oxidation produces 1.5055×10^{23} molecules of CO_2. Calculate the mass of glucose oxidised.

10. 11.25 g of hydrated copper sulphate, CuSO4.xH2O, is heated to drive off the water of crystallisation. The mass of the anhydrous copper sulfate was 7.19 g. Calculate the value of x in the formula.

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CHEMISTRY 1 Tutorial 01

Atomic Structure

1. For each of the following give the atomic number, the mass number and the numbers of protons, neutrons and electrons:
   ^{1}H, ^{2}D, ^{3}T, ^{4}He, α particle, ^{7}Li, ^{9}Be, ^{12}C, ^{20}Ne, ^{27}Al, ^{28}Al, ^{28}Si, ^{29}Si, ^{48}Ti, ^{137}Ba, ^{235}U, ^{238}U.

2. Describe Rutherford's famous gold foil experiment and explain how he interpreted his results to modify understanding of atomic structure.

3. Explain how the emission spectrum of hydrogen supports the theory that electrons exist in shells.

4. For each of the Lyman, Balmer and Paschen series of lines, calculate the wavenumber positions of the first three lines and the theoretical progression termination as $n_1 \rightarrow \infty$.

5. Convert the positions from the Balmer series in question 4 from wavenumber / cm^{-1} to wavelength / nm. Visible light covers what wavelength range? Use your answer to comment on the visibility of lines in the Balmer series.

6. Explain why the energies of the electron orbits are negative.

7. Explain how the emission spectrum of hydrogen supports Bohr's theory that electrons exist in shells.

8. For each of the Lyman, Balmer and Paschen series of lines, in the hydrogen emission spectrum, calculate the wavenumber, wavelength, frequency, energy in J and eV and molar energy of the first four lines and the theoretical progression termination as n1 $\rightarrow \infty$.

9. State the wavelength range of visible light and use your answer to comment on the visibility of lines in the Balmer series.

10. Detail the limitations of the Bohr model

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CHEMISTRY 1 Tutorial 02

Atomic Structure II

1. Describe what a wavefunction is
2. State the kinetic energy operator and the total energy, or Hamiltonian, operator
3. Describe the Born interpretation of the square of the modulus of the wavefunction.
4. Explain the meaning of the term degenerate as applied to orbitals.
5. Give values of n and l and state the number of possible values of m_l for each of the following orbitals: 1*s*, 2*p*, 3*d*, 3*p*, 4*s* and 5*s*.

6. Sketch the $2p_x$ $2p_y$ and $2p_z$ orbitals.

7. Sketch and name the five degenerate 3*d* orbitals. Explain the meaning of the term degenerate.

8. State the Aufbau principle, draw the Madelung diagram, state Hund's rule of maximum spin multiplicity and state the Pauli exclusion principle.

9. State the consequences of the Pauli exclusion principle for electronic configurations and use the above principles, diagram and rule to justify the duplet and octet rules and explain the circumstances under which each rule is applicable.

10. Give full and abridged (using Noble gas) the ground-state electronic configurations of the following: hydrogen, lithium, boron, nitrogen, fluorine, neon, sodium, magnesium, silicon, sulphur, phosphorous, chlorine and argon.

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CHEMISTRY 1 Tutorial 03

Molecular Structure

1. Draw Lewis structures for

HF, H_2O, H_2O_2, $AlCl_3$, CO_2, CO, CCl_4, PCl_3, PCl_5, H_2CCH_2, HCCH, HCN, HNC, SF_4, SF_6, ClF_5, IF_7, XeF_4.

2. Use VSEPR theory to predict the shapes and geometries of the molecules above.

3. From your knowledge of electronegativity indicate the polarity of the following bonds:
C–H, C–C, C=C, H–F, C=O, C–Br, Br–I and S=O.

4. What is the molecular shape of ClF_3? What is its most stable configuration? (Hint: there are three different, possible combinations of the same geometry)

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CHEMISTRY 1 Tutorial 04

Mendeleev's Periodic Table of the Elements

1. The table below gives successive ionisation energies of lithium, sodium and potassium.

Ionisation energy / kJ mol^{-1}	1st	2nd	3rd	4th
lithium	526	7310	11800	–
sodium	502	4560	6920	9540
potassium	425	3060	4440	5880

a) Explain the order of the first ionisation energies of the three elements.

b) Why is the second ionisation energy of each element much greater than the first?

c) Why is no value quoted for the fourth ionisation energy for lithium?

2. Which of the following has the highest 1st ionisation energy and why: H, Ne, Na, C & Cl?

3. Use your knowledge of ionisation energies to identify the elements of the second period from the table below of successive ionisation energies in kJ mol–1 .

element	1st IE / kJ mol^{-1}	2nd IE / kJ mol^{-1}	3rd IE / kJ mol^{-1}	4th IE / kJ mol^{-1}	5th IE / kJ mol^{-1}	6th IE / kJ mol^{-1}	7th IE / kJ mol^{-1}	8th IE / kJ mol^{-1}
①	1012	1907	2914	4964	6274	21267	25431	29872
②	496	4562	6910	9543	13354	16613	20117	25496
③	1000	2252	3357	4556	7004	8496	27107	31719
④	578	1817	2745	11577	14842	18379	23326	27465
⑤	738	1451	7733	10543	13630	18020	21711	25661
⑥	1521	2666	3931	5771	7238	8781	11995	13842
⑦	787	1577	3232	4356	16091	19805	23780	29287
⑧	1251	2298	3822	5159	6542	9362	11018	33604

4. Draw a sketch of the periodic table to show where the main blocks are located.

5. The elements given below have the following electronegativities:

Al 1.5, C 2.5, H 2.1, N 3.0, P 2.1, B 2.0, Cl 3.0, Li 1.0, Na 0.9, P 2.5, Be 1.5, F 4.0, Mg 1.2, O 3.5, Si 1.8

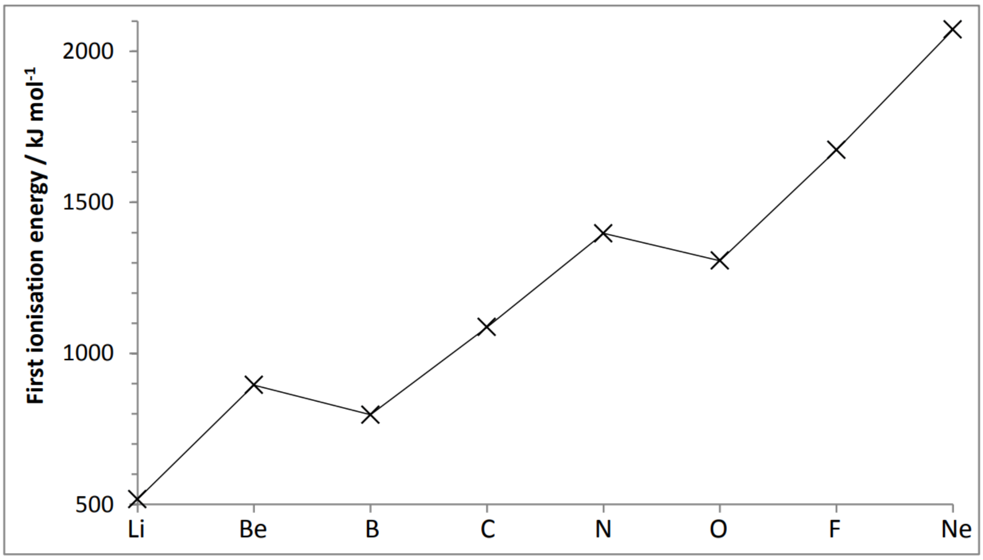
a) What do you understand by the term electronegativity?

b) Give and explain the relationship between electronegativity and the position of the elements along a period and down a Group?

c) In what major respect do electronegativity and electron affinity differ?

d) Arrange the following in order of increasing ionic character: CO_2, LiCl, BeH_2, BCl_3, NaCl, NH_3, PCl_3, LiF, and MgF_2.

6. Explain the first ionisation energies of the elements of the second period



7. Explain the trend in atomic radius for the elements of the second period.

8. Quote the highest and lowest electronegativities on the Pauling scale and explain why no values are quoted for He, Na and Ar.

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CHEMISTRY 1 Tutorial 05

Isotopes and Radioactivity

1. If the three isotopes of silicon: ^{28}Si, ^{29}Si and ^{30}Si have abundances of 92.2297%, 4.6832% and 3.0872% and atomic masses of 27.9769, 28.9765 and 29.9738 u respectively, determine the relative atomic mass of silicon.
2. The element Q has the electronic configuration $1s^22s^22p^63s^23p^64s^23d^{10}4p^1$.
   a) Write down the atomic number of Q
   b) Q occurs naturally as a mixture of ^{69}Q and ^{71}Q. Explain the significance of these numbers.
   c) If ^{69}Q and ^{71}Q occur in the proportions 60.109% and 39.892% and have atomic masses of 68.9256 and 70.9247 u respectively, calculate the relative atomic mass of Q.
   d) Calculate the mass defect of a ^{69}Q atom and hence its binding energy both per atom and in molar form.
3. a) What is meant by the term isotope?
   b) How could it be demonstrated that an element contained different isotopes?
4. a) If the radioactive decay of ^{63}Ni to ^{63}Cu has a half-life of 120 years, how long will it take for three quarters of the nickel to be changed to copper?
   b) Calculate the decay constant for ^{63}Ni.
   c) Write a nuclear equation for the decay of ^{63}Ni to ^{63}Cu and state what type of radioactive decay is occurring.
5. ^{238}U has a half-life of 4.468×10^9 years. Calculate how long it would take for the activity of a sample of ^{238}U to drop to 20% of its original value.
6. Look up the ^{238}U decay series and write nuclear equations for the fifteen radioactive decay processes that turn ^{238}U into stable ^{206}Pb.
7. Living matter has an activity of ca. 260 Bq kg $^{-1}$ owing to ^{14}C. If a sample of wood from an ancient burial site has an activity of 155 Bq kg $^{-1}$ estimate the age of the site, given the half-life of ^{14}C is 5730 years.

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CHEMISTRY 1 Tutorial 06

Structure of Solids

1. Describe the principle differences in bonding between metals, giant covalent structures, molecular crystals and ionic crystals. Give one example of each and for each structure relate the physical properties to the bonding.

2. Define the acronyms and give coordination numbers for hcp, ccp, fcc and bcc.

3. Caesium chloride is an ionic bcc structure. Draw the unit cell for caesium chloride and demonstrate the 1:1 ratio of Cs to Cl in the unit cell.

4. Prove that fcc and bcc fill space with 74 and 68% efficiencies respectively.

4. Calculate the 2θ position of a reflection from planes with a *d* spacing of 2.03 Å in a diffraction pattern recorded using Cu K_α X-rays of wavelength 154.18 pm.

5. Calculate the *d*-spacing of a reflection at 23 ° 2θ in a diffraction pattern recorded using Cu K_α X-rays of wavelength 154.18 pm.

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CHEMISTRY 1 Tutorial 07

Quantity Calculus

1. Derive the following compound units in terms of their base SI units:

a) watt, b) pascal, c) volt, d) ohm

2. Show the equivalence of the units in the following equations:

a) $pV = nRT$ b) $\bar{v} = \frac{1}{2\pi c}\sqrt{\frac{k}{\mu}}$ c) $n\lambda = 2d sin\theta$ d) $E = -\frac{m_e e^4}{8\varepsilon_0^2 h^2 n^2}$ e) $\Delta G = \Delta H - T\Delta S$

f) $\hat{p}_x\psi = -i\hbar\frac{\partial\psi}{\partial x}$ g) $\Delta E = hc\bar{\upsilon}$ h) $v_{RMS} = \sqrt{\frac{3RT}{M}}$ i) $k = Ae^{-\frac{E_a}{RT}}$ j) $\Delta G - nFE$

a) $pV = nRT$ b) $\bar{\upsilon} = \frac{1}{2\pi c}\sqrt{\frac{k}{\mu}}$ c) $n\lambda = 2d\sin\theta$ d) $E = \frac{m_e e^4}{8\varepsilon_0^2 n^2 h^2}$

ε_0 is the permittivity of free space and has units of $kg^{-1}\ m^{-3}\ s^4\ A^2$.

Whilst all these equations relate to chemistry, you may well need to look some of them up in order to identify the various quantities involved. Remember, scaling factors, like centi and milli, are irrelevant.

3. Use the equivalence of units on either side of an equation to determine the missing symbol in the following equation for the measurement of the surface tension of a fluid via the capilliary rise method.

$$\gamma = \frac{rg\,?\,h}{2\cos\theta}$$

(γ = surface tension of the fluid / N m^{-1}, r = radius of the capilliary, g = acceleration due to gravity, *?* = to be determined, h = height of the liquid rise, θ = contact angle).

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CHEMISTRY 1 Tutorial 08

Gases I and II

1. Calculate the conditions of STP and SATP in Pa, bar, mbar, atm, mmHg, Torr, K and °C.

2. Calculate the molar volume at STP and SATP in m^3 , dm^3 and mL to 3 s.f.

3. State Boyle's Law, Charles' Law and Avogadro's Law and use them to derive the Ideal Gas Equation.

4. a) A gas occupies 81.6 L at 21.3°C and 991 mbar. Calculate the volume at 57.6°C and 4.29 atm.
   b) A gas at 200.00°C occupies 4.51 m3 at 842 Torr. Calculate the temperature of the gas in 7.43 m^3 at 0.65 bar.
   c) A gas at 1 atm occupies 22.41 L at 0°C. Calculate the pressure of the gas in 24.79 L at 25°C.
   d) A gas occupies 200 mL at 17.7°C and 34.2 atm. Calculate the volume at 19.7°C and 1 bar.
   e) A gas at 760 mmHg occupies 15.41 m3 at 421.88 K. Calculate the pressure of the gas in 1.73 m^3 at 285.15 K.
   f) A gas at 16.0°C occupies 2.4 mL at 432 mmHg. Calculate the temperature of the gas in 7.0 mL at 2431 mmHg.
   g) A gas at –40.20°C occupies 37.6 dm^3 at 1008 mbar. Calculate the temperature of the gas in 1275 mL at 953 mbar.
   h) A gas occupies 75.76 m^3 at 312 K and 68000 Pa. Calculate the volume at 0°C and 760 mmHg.
   i) A gas at 300 bar occupies 900 L at 290 K. Calculate the pressure of the gas in 270 m^3 at 25°C.

5. a) Define the term compression factor.
   b) Discuss the applicability of the Ideal Gas Equation to real gases in terms of compression factor.
   c) Explain how limitations of the Kinetic Theory of Gases lead to the observed limited applicability of the Ideal Gas Equation.
   d) State the Van der Waals equation and explain how it accounts for the deficiencies of the Kinetic Theory of Gases

6. If the rate of effusion of H_2 through a pin-hole is measured to be 2.02 $cm^3\ s^{-1}$ and the rate of effusion of an unknown gas through the same pin-hole is measured to be 0.505 $cm^3\ s^{-1}$ what is the molar mass of the unknown gas and what is its density and likely identity?

7. Calculate the r.m.s. speed of H_2, O_2, N_2, CO_2 and H_2O molecules in a sample of air at 25 °C.

8. Define *mean free path* and *collision frequency*.

9. Using an appropriate diagram explain why dry ice (solid carbon dioxide) sublimes at room temperature and pressure.

10. Explain why the compression factor of all gases approaches 1 as ambient pressure falls towards zero.

11. Explain why the mean velocity and most probable velocity of gas particles are never identical.

PERIODIC TABLE OF THE ELEMENTS

1 **H** Hydrogen 1.0079								ATOMIC NUMBER **SYMBOL** NAME ATOMIC MASS									2 **He** Helium 4.003
3 **Li** Lithium 6.941	4 **Be** Beryllium 9.012											5 **B** Boron 10.811	6 **C** Carbon 12.011	7 **N** Nitrogen 14.007	8 **O** Oxygen 15.999	9 **F** Fluorine 18.998	10 **Ne** Neon 20.180
11 **Na** Sodium 22.990	12 **Mg** Magnesium 24.305											13 **Al** Aluminium 26.982	14 **Si** Silicon 28.086	15 **P** Phosphorus 30.974	16 **S** Sulphur 32.066	17 **Cl** Chlorine 35.453	18 **Ar** Argon 39.948
19 **K** Potassium 39.098	20 **Ca** Calcium 40.08	21 **Sc** Scandium 44.956	22 **Ti** Titanium 47.88	23 **V** Vanadium 50.942	24 **Cr** Chromium 51.996	25 **Mn** Manganese 54.938	26 **Fe** Iron 55.847	27 **Co** Cobalt 58.933	28 **Ni** Nickel 58.69	29 **Cu** Copper 63.546	30 **Zn** Zinc 65.39	31 **Ga** Gallium 69.723	32 **Ge** Germanium 72.61	33 **As** Arsenic 74.922	34 **Se** Selenium 78.96	35 **Br** Bromine 79.904	36 **Kr** Krypton 83.80
37 **Rb** Rubidium 85.47	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.906	40 **Zr** Zirconium 91.224	41 **Nb** Niobium 92.906	42 **Mo** Molybdenum 95.95	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.91	46 **Pd** Palladium 106.42	47 **Ag** Silver 107.87	48 **Cd** Cadmium 112.41	49 **In** Indium 114.82	50 **Sn** Tin 118.17	51 **Sb** Antimony 121.75	52 **Te** Tellurium 127.60	53 **I** Iodine 126.90	54 **Xe** Xenon 131.29
55 **Cs** Caesium 132.90	56 **Ba** Barium 137.33	57 **La** Lanthanum 138.91	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.95	74 **W** Tungsten 183.85	75 **Re** Rhenium 186.21	76 **Os** Osmium 190.2	77 **Ir** Iridium 192.22	78 **Pt** Platium 195.08	79 **Au** Gold 196.97	80 **Hg** Mercury 200.59	81 **Tl** Thallium 204.38	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.98	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Unq** _____ (261)	105 **Unp** _____ (262)	106 **Unh** _____ (263)	107 **Uns** _____ (262)	108 **Uno** _____ (265)	109 **Une** _____ (266)	110 **Uun** _____ (267)								

58 **Ce** Cerium 140.12	59 **Pr** Praseodymium 140.91	60 **Nd** Neodymium 144.24	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.96	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.92	66 **Dy** Dysprosium 162.50	67 **Ho** Holmium 164.93	68 **Er** Erbium 167.26	69 **Tm** Thulium 168.93	70 **Yb** Ytterbium 173.04	71 **Lu** Lutetium 174.97
90 **Th** Thorium 232.04	91 **Pa** Protactinium 231	92 **U** Uranium 238.03	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (260)