CH10009 Workshop Questions

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Contents

Welcome

The notes have been prepared in a package called BookDown for RStudio so that the equations are accessible to screen readers. However, by providing the notes as a .html webpage I can also embed short videos to further describe some of the topics. Further you can download the questions (and later the answers, top left of the screen) in a format that suits you (either pdf or epub) to view offline, or change the way this document appears for ease of reading.

If you spot any typos or think there are any errors please let me know and I will do my best to fix them.

Workshops for CH10009

The topics for LOILS each week are as follows:

- Week 1: General Q&A
- Week 2: Rearranging equations, units and standard form
- Week 3: Logarithms and exponentials
- Week 4: Tables and graphs
- Week 5: Calculus - differentiation - the basics and the chain rule
- Week 6: Calculus - differentiation - the product rule and partial differentiation
- Week 7: Calculus - integration - the basics and definite integrals
- Week 8: Some more examples of integration and revision

This 'book' will be updated weekly with workshop questions, answers will be provided and some answers will include 'process' as well as answer. Please contact me if you need help.

I am using this format as it is an accessible format.

Version history

Week 2 workshop released 12th October 2020.

Some more video answers for workshop 1 embedded 11th October 2020.

Video answers for workshop 1 embedded 09th October 2020.

The initial commit of this book is dated 2nd October 2020.

Chapter 1

Week 1

1.1 Preliminary infomation

1.1.1 SI base units

The SI system of base units has seven fundamental units from which the others are derived.

Table 1.1: The seven base units from which all others are dervied.

SI base unit	symbol	quantity symbol (dimension)	quantity
kilogram	kg	M	mass
metre	m	L	length
second	s	T	time
ampere	A	I	electric current
kelvin	K	Θ	temperature
mole	mol	N	amount of substance
candela	cd	J	luminous intensity

1.1.2 SI Derived units

Table 1.2: Some common SI derived units used in chemistry.

symbol	SI derived unit	quantity	SI base units	other SI units
Hz	hertz	frequency	s^{-1}	
N	newton	force	$kg\ m\ s^{-2}$	
Pa	pascal	pressure	$kg\ m^{-1}\ s^{-2}$	$N\ m^{-2}$

symbol	SI derived unit	quantity	SI base units	other SI units
J	joule	energy	kg m^2 s^{-2}	N m
W	watt	power	kg m^2 s^{-3}	J s^{-1}
C	coulomb	electrical charge	A s	
V	volt	electrical potential	kg m^2 s^{-3} A^{-1}	J C^{-1}
F	farad	electrical capacitance	kg^{-1} m^{-2} s^4 A^2	C V^{-1}
Ω	ohm	electrical resistance	kg m^2 s^{-3} A^{-2}	V A^{-1}
S	siemens	electrical conductance	kg^{-1} m^{-2} s^3 A^2	A V^{-1} or 1/Ω

1.1.3 Other units and conversion factors

There are a number of non-SI base or derived units which are in common usage which are useful to know and be able to convert between. Table 1.3 contains a number of useful unit conversions.

Table 1.3: The relationship between some other common units and the SI system.

unit	quantity	SI equivalant
torr (or mm Hg)	pressure	$\frac{101325}{760}$ Pa
atm	pressure	101325 Pa
bar	pressure	100000 Pa
eV	energy	$1.602176634 \times 10^{-19}$ J
cal	energy	4.184 J
Å	length	1×10^{-10} m

There are myriad other units in use, either with historical or geographic preference, or just for niche purposes (where would we be without olympic swimming pools or London buses). Examples such as the mile, furlong or beard-second are all units of length.

Further, the unit ºC is formally an SI derived unit. The temperature in Kelvin is:

$$T(\mathrm{K}) = T(\mathrm{K}) + 273.15$$

1.1.4 SI prefixes and standard form

In general lower case prefixes are used for negative powers and upper case prefixes are used for positive powers, however k (kilo) is an obvious exception to this rule. (Other exceptions are da (deca, 10^1) and h (hecto, 10^2)).

Table 1.4: The more common SI prefixes used in chemistry.

SI prefix	SI prefix 'name'	standard form multiplier
y	yocto	10^{-24}
z	zepto	10^{-21}
a	atto	10^{-18}
f	femto	10^{-15}
p	pico	10^{-12}
n	nano	10^{-9}
	micro	10^{-6}
m	milli	10^{-3}
c	centi	10^{-2}
d	deci	10^{-1}
k	kilo	10^{3}

1.2 Questions

1.2.1 Rearranging equations

Answers for these questions are in Section 1.3.1.

For each of the following rearrange to make the specified variable the subject of the equation.

1. $[A] = [A]_0 - kt$, t
2. $E = \frac{1}{2}mv^2$, v
3. $F = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$, r
4. $\frac{1}{[A]} = \frac{1}{[A]_0} + kt$, $[A]_0$
5. $\ln(x_A) = -\frac{\Delta H}{R}(\frac{1}{T_1} - \frac{1}{T_2})$, T_1
6. $K_a = \frac{\alpha^2 c}{1-\alpha}$, α

1.2.2 Unit conversion questions

Answers for these questions are in Section 1.3.2.

1. Convert the following:
   a. 3.4 µm to mm and m
   b. 270.4 g mol^{-1} to kg mol^{-1} and yg ($molecule^{-1}$)
   c. 23.4 g dm^{-3} to mg dm^{-3}, g m^{-3}, and kg m^{-3}
   d. 17.5 µHz to Hz
   e. 5796 cm^{-1} to $µm^{-1}$ and m^{-1}

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2. If a box has dimensions 0.234 m x 34.5 cm x 26.8 mm. What is the volume of the box in:
   a. cm^3?
   b. dm^3?
   c. m^3?
   d. $Å^3$?

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3. The Gibbs free energy of a reaction, ΔG is given by equation (1.1).

$$\Delta G = \Delta H - T\Delta S \tag{1.1}$$

Determine the value of ΔG at 40 ºC when the enthalpy of reaction, ΔH = -10.235 kJ mol^{-1} and the molar entropy, ΔS = +34 J K^{-1} mol^{-1}

1.2.3 Determining units of variables in equations

Answers for these questions are in Section 1.3.3.

1. The ideal gas equation is given in equation (1.2).

$$pV = n\mathrm{R}T \tag{1.2}$$

The units of the variables are: p (pressure), Pa (pascals) V (volume), m^3 n (number of moles), mol T (absolute temperature), K

   a. Determine the SI base units of the gas constant, R.

   b. Determine the pressure in mmHg of 1.00 mmol of an ideal gas that occupies 1.65 dm^3 at 25 ºC.

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2. The famous Einstein equation $E = mc^2$ is more properly written as:

$$E^2 = p^2c^2 + m_0^2c^4$$

Determine the units of the variable p.

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3. At low temperatures the molar heat capacity of a material $C_{p,m}$ (J K^{-1} mol^{-1}) is given by equation (1.3).

$$C_{p,m} = aT^3 \tag{1.3}$$

Determine the units of the constant, a.

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4. Determine the units of the coulomb constant, k_e, in equation (1.4), given that r is the separation of two charges, F the force of attraction between the two charges, and q_x is the charge (in coulombs, C) on each of the particles.

$$F = k_e \frac{q_1 q_2}{r^2} \tag{1.4}$$

1.3 Answers

1.3.1 Rearranging equations answers

1. $t = \frac{[A]_0 - [A]}{k}$
2. $v = \sqrt{\frac{2E}{m}}$
3. $r = \sqrt{\frac{q_1 q_2}{4\pi\varepsilon_0 F}}$
4. $[A]_0 = \frac{[A]}{1-[A]kt}$
5. $\frac{\Delta H T_2}{\Delta H - RT \ln x_A}$

1. $\alpha = \frac{-K_a \pm \sqrt{K_a^2 + 4cK_a}}{2c}$

1.3.2 Unit conversion answers

1. a. 3.4×10^{-3} mm; 3.4×10^{-6} m
   b. 0.2704 kg mol^{-1}; 449.0 yg
   c. 23.4×10^{-3} mg dm^{-3}; 23.4×10^{-3} g m^{-3}; and 23.4×10^{-6} kg m^{-3}
   d. 17.5×10^{-6} Hz
   e. 0.5796 µm^{-1} and 5.796×10^5 m^{-1}

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2. a. 2.16×10^3 cm^3
   b. 2.16 dm^3
   c. 2.16×10^{-3} m^3
   d. 2.16×10^{27} Å^3

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3. -21 kJ mol^{-1} - please note this value is correct to the appropriate sig figs

1.3.3 Determining units of variables in equations answers

1. a. • kg m^{2} s^{-2} K^{-1} mol^{-1} (this is more ususally written as J K^{-1} mol^{-1})
   b. • 11.3 mm Hg (1.50 kPa)

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2. kg m s^{-1}

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3. J K^{-4} mol^{-1}

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4. kg m^{3} s^{-4} A^{-2} or N m^{2} C^{-2}

Chapter 2

Week 2

2.1 Preliminary infomation

2.1.1 Rules of powers and exponents

$$m^a \times m^b = m^{a+b} \tag{2.1}$$

$$\frac{p^a}{p^b} = p^{a-b} \tag{2.2}$$

$$\left(q^a\right)^b = q^{a \times b} \tag{2.3}$$

Anything raised to the power 0 is equal to 1.

$$x^0 = 1$$

Roots may be expressed as fractional powers:

$$\sqrt[n]{x} = x^{\frac{1}{n}} \tag{2.4}$$

When we see negative powers it is the same as the inverser of the positive power.

$$x^{-n} = x^{\frac{1}{x^n}} \tag{2.5}$$

2.1.2 Rules of logs

Logs are the inverse function of exponents, and can have many bases:

When we use 'natural logs' we use the terminology ln, a natural log is the inverse of 'e'.

$$x = \ln e^x \tag{2.6}$$

Other logs are ususally marked with the *base*, however if no base is indicated it should be considered that this is $\log_{10}$.

$$x = \log_{10} 10^x \tag{2.7}$$

When combining logs (these rules are the same regardless of base):

$$\log_x A + \log_x B = \log_x (AB) \tag{2.8}$$

$$\log_x A - \log_x B = \log_x \left(\frac{A}{B}\right) \tag{2.9}$$

$$\log_x (A^n) = n \log_x A \tag{2.10}$$

If we want to change the bases of logs (such as in the Beer-Lambert law):

$$log_b A = \frac{\log_x A}{\log_x b} \tag{2.11}$$

2.2 Questions

2.2.1 Simple log practice

Answers for these questions are in Section 2.3.1.

Evaluate the following expressions:

1. $\log_{10} 10^6$
2. $\log_{10} 10^{-5}$
3. $\log_{10}(5^4 \times 3^{-2})$
4. $\ln \pi 6^2$
5. $e^{\log_e x} = \ln y$

2.2.2 Rearranging equations

Answers for these questions are in Section 2.3.2

1. Rearrange the following to make the highlighted term the subject:
   a. $\Delta S = k_B \ln W$, W
   b. $\Delta S = nR \ln \frac{V_f}{V_i}$, V_f
   c. $\nu = \frac{1}{2\pi}\left(\frac{k}{\mu}\right)^{\frac{1}{2}}$, μ
   d. $\ln K = \frac{nFE}{RT}$, E
   e. $\ln K' - \ln K = \frac{\Delta H}{R}\left(\frac{1}{T} - \frac{1}{T'}\right)$, ΔH

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2. The integrated rate equation for a first order reaction is $[A] = [A]_0 e^{-kt}$.
   a. Rearrange this equation in order to make k the subject.
   b. What units must k have?

2.2.3 pH question.

Answers for these questions are in Section 2.3.3

HCl fully dissociates in water. If 5 cm^3 (measured using a glass pipette) of 38% w/w HCl solution ($\rho = 1.189$ kg dm^{-3}) is 'added to 20 cm^3 water'made up' in a 25 cm^3 standard flask.

a. What is the pH of the resulting solution?
b. What mass of NaOH is required to neutralise the resulting solution?

Hint: w/w means weight-weight, i.e. the number of g in 100 g. In this case 38 g of HCl in 100 g total of mixture.

Hint: you will need to think about units and rearranging equations from Week 1.

2.2.4 pK$_\mathrm{a}$ question.

Answers for these questions are in Section 2.3.4

The degree of dissociation of an acid, α is related to the acid dissociation constant, K_a and the concentration of the acid, c, as shown in equation (2.12)

$$K_a = \frac{\alpha^2 c}{1-\alpha} \tag{2.12}$$

Determine the pH of hydrofluoric acid solutions (p$K_a = 3.18$) when the concentration of acid is:

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a. 1.00 M
a. 2.50 mM
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Hint: We rearranged this equation last week for α

2.3 Answers

2.3.1 Simple log practice answers

1. 6
2. -5
3. 1.841...
4. 4.728...
5. $x = \ln y$

2.3.2 Rearranging equations answers

1. Rearrange the following to make the highlighted term the subject:
   a. $W = e^{\frac{\Delta S}{k_B}}$
   b. $V_f = V_i e^{\frac{\Delta S}{nR}}$
   c. $\mu = \frac{1}{4\pi^2}\frac{k}{\nu^2}$
   d. $E = \frac{RT}{nF}\ln K$
   e. $\Delta H = \left(\frac{TT'}{T'-T}\right) R \ln \frac{K'}{K}$

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2. a. $k = \frac{\ln[A]_0 - \ln[A]}{t}$
   b. s^{-1}

2.3.3 pH answer

a. pH -0.394
b. $m_{\text{NaOH}} = 2.5$ g

2.3.4 pK_a answer

a. Two roots: 0.025 and -0.026 and we can't have a negative degree of dissociation. pH 1.6
b. Two roots: 0.40 and -0.66 and we can't have a negative degree of dissociation. pH 3.0