Metabolic Calculations of Indirect Calorimetry

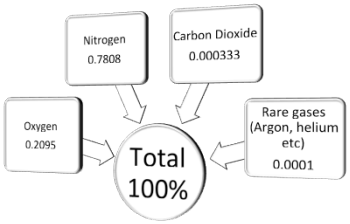
- Understanding atmospheric air and gas volumes
- Calculating VO2
- The Haldane Transformation
- Calculating VCO2
- Calculating RER
- Calculating caloric expenditure

Expired gas analysis

- 4 key variables of measurement

1. VE = expired volume
2. VI = inspired volume
3. FEO2 = fraction of expired O2
4. FECO2 = fraction of expired CO2

Review of gas fractions in atmospheric air



Gas Conditions

Inspired and expired gas conditions are influenced by:

- Gas temperature – colder reduces volume
- Gas pressure – lower pressure increases volume
- Water vapor content – depends on temperature

We need to standardize these conditions!

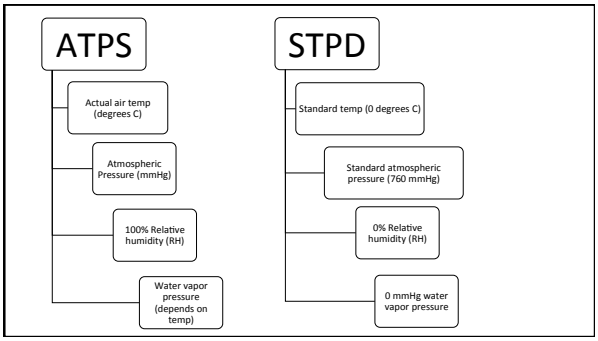
Understanding ATPS and STPD

ATPS = Atmospheric Temperature and Pressure, Saturated

- Measured air temp (˚C)
- Measured Pressure (mmHg)
- Relative humidity (100%)

STPD = Standard Temperature and Pressure, Dry

- 273 ˚K = 0 ˚C
- Sea level = 760 mmHg
- Relative humidity (0%)



Temp (°C)	P_{H2O} (mmHg)
14	12.9
15	13.5
16	14.1
17	14.9
18	15.5
19	16.5
20	17.5
21	18.7
22	19.8
23	21.1
24	22.4
25	23.8
26	25.2
27	26.7
28	28.3
29	30.0
30	31.8
31	33.7
32	35.7
33	37.7
34	39.9
35	42.2
36	44.6
37	47.1
38	49.4
39	52.0
40	54.7

Water vapor pressures for fully saturated air RH = 100%

Converting ATPS to STPD

- We measure expired volume, air temperature, barometric pressure, and use our water vapor pressure chart

$$VE_{STPD} = VE_{ATPS} * (273 / (273 + T_{room})) * ((P_B - P_{H2O}) / 760)$$

- VE_{ATPS}: Measured VE
- T_{room}: Temp in ºC
- P_B: Measured mmHg
- P_{H2O}: Use chart

Quiz!

- What are the major factors that impact gas volume?
- What is the difference between ATPS and STPD?
- Why do we use STPD for indirect calorimetry calculations?

Expired gas analysis calculations

1. Convert ATPS to STPD
2. Calculate VO2
3. Calculate VCO2
4. Calculate RER
5. Calculate caloric expenditure

Let's examine the formulas we need!

Calculating VO2

- VO2 = inspired O2 – expired O2
- VO2 = (VI x FIO2) – (VE x FEO2)

We know FIO2 = 0.2095

VO2= (VI x .2095) – (VE x FEO2)

Calculating VCO2

- VCO2 = expired CO2 – inspired CO2
- VCO2 = (VE x FECO2) – (VI x FICO2)

We know FICO2 = 0.000333

VCO2 = (VE x FECO2) – (VI x .000333)

How do we calculate VI??

Calculating VI

- We measure VE, FEO2, FECO2, and calculate VI… how?

HALDANE TRANSFORMATION

We must use the Haldane transformation to solve for VI!

Haldane Transformation

Nitrogen is an inert gas
It is NOT physiologically active

Haldane Transformation

FEN2 + FEO2 + FECO2 = 1

FEN2 = 1 – (FEO2 + FECO2)

FEN2 = 0.99063 – (FEO2 + FECO2)

Rare gases correction

Solving for Inspired Volume (VI)

We know…

(VI x FIN2) = (VE x FEN2)

Thus…

VI = VE (FEN2/FIN2)

Solving for VI

We know FIN2 = 0.7808

And…

FEN2 = 0.99063 – (FE02 + FECO2)

Thus, if VI = VE (FEN2/FIN2)

VI = VE (0.99063 – (FEO2 + FECO2)) / 0.7808

FEN2 FIN2

Let's go back to VO2!

Calculate VO2

Remember…

• VO2 = (VI x .2095) – (VE x FEO2)

Substitute Haldane Transformation for VI

VO2 = ((VE(0.99063-(FEO2 + FECO2))/.7808) x .2095) – (VE x FEO2)

We have all our variables!

Calculate VCO2

• Remember…
VCO2 = (VE x FECO2) – (VI x FICO2)

VCO2 = (VE x FECO2) – (VI x .000333)

Use the values from the VO2 equation for VI, and then substitute VE, and FECO2

Calculate RER

• After you calculate VO2 and VCO2, calculate RER

RER = VCO2/VO2

Calculation Steps

1. Change ATPS to STPD
2. Calculate VO2
3. Calculate VCO2
4. Calculate RER
5. Calculate caloric expenditure

Computation Examples in Indirect Calorimetry

Tr = 24.0 °C; P_B = 635 mmHg; RH = 100%

Time (min)	VE (ATPS)	FEO2	FECO2
2	9.35	0.1658	0.0390
4	35.14	0.1496	0.0480
8	72.37	0.1575	0.0499
12	175.03	0.1784	0.0362

Step 1: Convert ATPS to STPD

- ***T_{room} = 24.0 °C; P_B = 635 mmHg; RH = 100%***
- ***VE_{ATPS} = 9.35; FEO2 = 0.1658; FECO2 = 0.0390***

$VE_{STPD} = VE_{ATPS} * (273 / (273 + T_{room})) * ((P_B – P_{H2O}) / 760)$

VE_{STPD}= 9.35 * (273 / (273 + 24.0)) * ((635 – 22.4) / 760)

VE_{STPD} = 9.35 * (0.919) * (0.806)

VE_{STPD} = 6.93 L/min

Temp (°C)	P_{H2O} (mmHg)
14	12.0
15	13.5
16	14.1
17	14.9
18	51.5
19	16.5
20	17.5
21	18.7
22	19.8
23	21.1
24	22.4
25	23.8
26	25.2
27	26.7
28	28.3
29	30.0
30	31.8
31	33.7
32	35.7
33	37.7
34	39.9
35	42.2
36	44.6
37	47.1
38	49.4
39	52.0
40	54.7

Step 2: Calculate VO2

VO2 = (VI x .2095) – (VE x FEO2)
Substitute Haldane Transformation for VI

VO2 = ((VE x (.99063-(FEO2 + FECO2)) / .7808) x .2095) – (VE x FEO2)
VO2 = ((6.93 x (0.99063 – (0.1658 + 0.0390)) / .7808) x .2095) – (6.93 x 0.1658)
VO2 = (6.974 x .2095) – (6.93 x 0.1658)

VO2 = 0.312 L/min

Step 3: Calculate VCO2

VCO2 = (VE x FECO2) – (VI x .000333)

VCO2 = (6.93 x 0.0390) – (6.974 x .000333)
VCO2 = 0.270 - 0.0023

VCO2 = 0.268 L/min

Step 4: Calculate RER

RER = VCO2 / VO2

RER = 0.268 / 0.312

RER = 0.859

One more step!
Step 5

Calculate Caloric Expenditure

Calculating Energy Expenditure

- To calculate energy expenditure most accurately, you need to know the following:
  1. VO_2
  2. RER
  3. RER caloric equivalent
  4. Exercise duration

Kcal= VO_2 (L/min) x RER caloric equivalent x time (min)

↑

Use non-protein RER chart

Let's calculate caloric expenditure!

VO_2 = 0.312 L/min
RER = 0.86
Duration = 2.0 min

Kcal = 0.312 (L/min) x 4.875 x 2.0 (min)

= **3.042 kcal in 2 min**

RQ	kcal/L O_2	% CHO*	kcal/L O_2 CHO	% FAT	kcal/L O_2 FAT
1.00	5.047	100.00	5.047	0.0	0.000
0.99	5.035	96.80	4.874	3.18	0.160
0.98	5.022	93.60	4.701	6.37	0.230
0.97	5.010	90.40	4.529	9.58	0.480
0.96	4.998	87.20	4.358	12.80	0.640
0.95	4.985	84.00	4.187	16.00	0.798
0.94	4.973	80.70	4.013	19.30	0.960
0.93	4.961	77.40	3.840	22.60	1.121
0.92	4.948	74.10	3.666	25.90	1.281
0.91	4.936	70.80	3.495	29.20	1.441
0.90	4.924	67.50	3.324	32.50	1.600
0.89	4.911	64.20	3.153	35.80	1.758
0.88	4.899	60.80	2.979	39.20	1.920
0.87	4.886	57.50	2.810	42.50	2.077
0.86	4.875	54.10	2.637	45.90	2.238
0.85	4.862	50.70	2.465	49.30	2.397
0.84	4.850	47.20	2.289	52.80	2.561
0.83	4.838	43.80	2.119	56.20	2.719
0.82	4.826	40.30	1.944	59.70	2.880
0.81	4.813	36.90	1.776	63.10	3.037
0.80	4.801	33.40	1.603	66.60	3.197
0.79	4.788	29.90	1.432	70.10	3.356
0.78	4.776	26.30	1.256	73.70	3.520
0.77	4.764	22.30	1.062	77.20	3.678
0.76	4.751	19.20	0.912	80.80	3.839
0.75	4.739	15.60	0.739	84.40	4.000
0.74	4.727	12.00	0.567	88.00	4.160
0.73	4.714	8.40	0.396	91.60	4.318
0.72	4.702	4.76	0.224	95.20	4.476
0.71	4.690	1.10	0.052	98.90	4.638
0.707	4.686	0.0	0.000	100.00	4.686

We can also examine fuel utilization!

3.042 kcal

CHO = 3.042 x .5410
1.645 kcal CHO

FAT = 3.042 x .4590
1.396 kcal FAT

RQ	kcal/L O_2	% CHO*	kcal/L O_2 CHO	% FAT	kcal/L O_2 FAT
1.00	5.047	100.00	5.047	0.0	0.000
0.99	5.035	96.80	4.874	3.18	0.160
0.98	5.022	93.60	4.701	6.37	0.230
0.97	5.010	90.40	4.529	9.58	0.480
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0.82	4.826	40.30	1.944	59.70	2.880
0.81	4.813	36.90	1.776	63.10	3.037
0.80	4.801	33.40	1.603	66.60	3.197
0.79	4.788	29.90	1.432	70.10	3.356
0.78	4.776	26.30	1.256	73.70	3.520
0.77	4.764	22.30	1.062	77.20	3.678
0.76	4.751	19.20	0.912	80.80	3.839
0.75	4.739	15.60	0.739	84.40	4.000
0.74	4.727	12.00	0.567	88.00	4.160
0.73	4.714	8.40	0.396	91.60	4.318
0.72	4.702	4.76	0.224	95.20	4.476
0.71	4.690	1.10	0.052	98.90	4.638
0.707	4.686	0.0	0.000	100.00	4.686

Computation Examples in Indirect Calorimetry

Tr = 24.0 °C; P_B = 635 mmHg; RH = 100%

Time (min)	VE (ATPS)	FEO2	FECO2
2	9.35	0.1658	0.0390
4	35.14	0.1496	0.0480
8	72.37	0.1575	0.0499
12	175.03	0.1784	0.0362

Step 1: Convert ATPS to STPD

- ***T_{room} = 24.0 °C; P_B = 635 mmHg; RH = 100%***
- ***VE_{ATPS} = 35.14; FEO2 = 0.1658; FECO2 = 0.0390***

$VE_{STPD} = VE_{ATPS} * (273 / (273 + T_{room})) * ((P_B – P_{H2O}) / 760)$

VE_{STPD}= 35.14 * (273 / (273 + 24.0)) * ((635 – 22.4) / 760)

VE_{STPD} = 35.14 * (0.919) * (0.806)

VE_{STPD} = 26.04 L/min

Temp (°C)	P_{H2O} (mmHg)
14	12.0
15	13.0
16	14.1
17	14.9
18	51.5
19	16.5
20	17.5
21	18.7
22	19.8
23	21.1
24	22.4
25	23.8
26	25.2
27	26.7
28	28.3
29	30.0
30	31.8
31	33.7
32	35.7
33	37.7
34	39.9
35	42.2
36	44.6
37	47.1
38	49.4
39	52.0
40	54.7

Step 2: Calculate VO2

VO2 = (VI x .2095) – (VE x FEO2)
Substitute Haldane Transformation for VI

VO2 = ((VE x (.99063-(FEO2 + FECO2)) / .7808) x .2095) – (VE x FEO2)
VO2 = ((26.04 x (0.99063 – (0.1496 + 0.0480)) / .7808) x .2095) – (26.04 x 0.1496)
VO2 = (26.04 x .2095) – (26.04 x 0.1496)

VO2 = 1.645 L/min

Step 3: Calculate VCO2

VCO2 = (VE x FECO2) – (VI x .000333)

VCO2 = (26.04 x 0.0480) – (26.04 x .000333)
VCO2 = 1.249 - 0.0023

VCO2 = 1.242 L/min

Step 4: Calculate RER

RER = VCO2 / VO2

RER = 1.242 / 1.645

RER = 0.755

Step 5: Calculate Caloric Expenditure

VO_2 = 1.645 L/min
RER = 0.755
Duration = 4.0 min

Kcal = 1.645 (L/min) x 4.751 x 4.0 (min)

= **31.262 kcal in 4 min**

RQ	kcal/L O_2	% CHO*	kcal/L O_2 CHO	% FAT	kcal/L O_2 FAT
1.00	5.047	100.00	5.047	0.0	0.000
0.99	5.035	96.80	4.874	3.18	0.160
0.98	5.022	93.60	4.701	6.37	0.230
0.97	5.010	90.40	4.629	9.58	0.480
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0.93	4.961	77.40	3.840	22.60	1.121
0.92	4.948	74.10	3.666	25.90	1.281
0.91	4.936	70.80	3.495	29.20	1.441
0.90	4.924	67.50	3.324	32.50	1.600
0.89	4.911	64.20	3.153	35.80	1.758
0.88	4.899	60.80	2.979	39.20	1.920
0.87	4.887	57.50	2.810	42.50	2.077
0.86	4.875	54.10	2.637	45.90	2.238
0.85	4.862	50.70	2.465	49.30	2.397
0.84	4.850	47.20	2.289	52.80	2.561
0.83	4.838	43.80	2.119	56.20	2.719
0.82	4.825	40.30	1.944	59.70	2.880
0.81	4.813	36.90	1.776	63.10	3.037
0.80	4.801	33.40	1.603	66.60	3.197
0.79	4.788	29.90	1.432	70.10	3.356
0.78	4.776	26.30	1.256	73.70	3.520
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0.76	4.751	19.20	0.912	80.80	3.839
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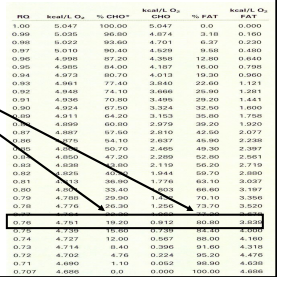
0.71	4.690	1.10	0.052	98.90	4.638
0.707	4.686	0.0	0.000	100.00	4.686

Fuel Utilization

31.262 kcal

CHO = 31.262 x .1920
6.002 kcal CHO

FAT = 31.262 x .8080
25.259 kcal FAT



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0.88	4.899	60.80	2.979	39.20	1.920
0.87	4.887	57.50	2.810	42.50	2.077
0.86	4.875	54.10	2.637	45.90	2.238
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0.83	4.838	43.80	2.119	56.20	2.719
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0.707	4.686	0.0	0.000	100.00	4.686

Assignment

- Finish the rest of the calculations in your handout
- Answers to each question will be posted online
- Show all of your work