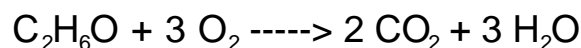


## RQ and Power Problems -- SOLUTIONS

### Animal Physiology

1. Calculate the RQ for the aerobic metabolism of ethanol,  $\text{CH}_3\text{CH}_2\text{OH}$ .

Balance the equation for complete oxidation of ethanol to water and  $\text{CO}_2$ :



$$\text{RQ} = \frac{M_{\text{CO}_2}}{M_{\text{O}_2}} \quad (\text{obviously molar amounts can be used just as well as volumes since both are gases and } 22.4 / 22.4 = 1)$$

thus, **RQ = 2/3 = 0.66**

2. Suppose that a migrating Monarch butterfly has a mass-specific oxygen consumption of  $10 \text{ mlO}_2 \text{ g}^{-1} \text{ h}^{-1}$  and it is using stores of fat as fuel since there are no flowers.

(a) Calculate its  $\dot{V}_{\text{CO}_2}$ .

Since the RQ for fat is about 0.71 (0.7 is good enough), then:

$$\text{RQ} = V_{\text{CO}_2} / V_{\text{O}_2}$$

or

$$V_{\text{CO}_2} = \text{RQ} * V_{\text{O}_2} = 0.71 * 10 \text{ ml}/(\text{gh}) = \mathbf{7.1 \text{ ml CO}_2 / (\text{gh})}$$

(b) Calculate its mass-specific power (watts  $\text{g}^{-1}$ ) (see table of RQ energy equivalents).  
*For the purpose of practice, I urge you to make the calculation using the Kcal equivalent of  $\text{O}_2$ , not the KJ equivalent.*

From the table, if RQ = 0.71, then  $1 \text{ LO}_2 = 19.8 \text{ Kcal}$  or  **$1 \text{ ml} = 4.73 \text{ cal}$**

We need to convert  $\text{ml O}_2 / (\text{gh})$  to calories/ $(\text{gh})$  to watts. Thus:

$$\dot{V}_{\text{O}_2} * \text{cal}/\text{mlO}_2 * \text{joules} / \text{cal} * \text{hour}/\text{sec}$$

$$10 \text{ mlO}_2 / (\text{gh}) * 4.73 \text{ cal}/\text{mlO}_2 * 4.184 \text{ J}/\text{cal} * 1 \text{ h} / 3600 \text{ s}$$

$$= \mathbf{0.055 \text{ w/g (55 milliwatts/g)}}$$

(c) Suppose that the costs of flight are always constant but that now the Monarch is able to feed on flowers and its RQ shifts to 1.0. What is its  $\dot{V}_{O_2}$ ?  $\dot{V}_{CO_2}$ ? (keep all of these mass specific). *For the purpose of practice, I urge you to make the calculation using the Kcal equivalent of  $O_2$ , not the KJ equivalent.*

This one is a bit tougher but it is simply the reverse of the last process. The main thing to keep in mind is that we learned the metabolic cost of flight in the last problem -- it is 0.23 w/g. This will not change when the fuel changes from fat to carb.

$\dot{V}_{O_2}$  in ml $O_2$ /(gh) at RQ =1: energy cost (w/g)\*sec \* s/h \* cal/J /  $V_{O_2}$  per cal  
so:

$$0.055 \text{ w/g (i.e., J/(gs))} * 3600\text{s/h} * 1 \text{ cal/} 4.184 \text{ J} / 5.04 \text{ mlO}_2/\text{cal}$$

$$\dot{V}_{O_2} = \mathbf{9.4 \text{ mlO}_2/(\text{gh})} \text{ and since RQ =1, } \dot{V}_{CO_2} = \mathbf{9.4 \text{ ml CO}_2/(\text{gh})}$$

3. A typical value of  $\dot{V}_{O_2}$  for a resting adult human is 220 ml  $O_2$  min<sup>-1</sup>. Calculate her  $\dot{M}_{O_2}$ .

This one's a cinch -- just convert to mols. Let's assume that  $\dot{V}_{O_2}$  is already at STP (that is how it is normally reported). So, 1 mol  $O_2$  = 22.4 LO $_2$ :

$$\dot{M}_{O_2} = 0.22 \text{ L } O_2 / \text{min} / 22.4 \text{ L/mol} = \mathbf{0.0098 \text{ mls } O_2 / \text{min} \text{ or } 9.8 \text{ m mols / min}}$$

4. A running tarantula used a total amount of oxygen during its run of 22.4 ml  $O_2$ . At the start of the exercise, it had a total body d-lactic acid concentration of 1 millimol; at the finish of exercise the total body lactate was 11 millimols.

To do this problem, assume that all hexose comes from glycogen. Look in packet #3 to find the net energetic yields of ~P for each process starting with glycogen.

**(a) How many total mols of ~P were synthesized during the exercise?**

The synthesized ATP is the sum of ~P synthesized in aerobic plus that synthesized in anaerobic metabolism.

**Aerobic** If we start from glycogen, we know that we conserve 37 mols of ~P in ATP per mol of hexose and we use 6 mols of O<sub>2</sub> to do this (see notes). Thus, **for each mol of O<sub>2</sub> used, we get 37 / 6 = 6.17 mols ~P.**

Now, our spider used 22.4 ml O<sub>2</sub> in its run -- i.e. 0.0224 L O<sub>2</sub>. Since there are 22.4 liters in a mol, then **M<sub>O<sub>2</sub></sub> for the spider was 0.0224 / 22.4 = 0.001 mols or 1 millimol.**

Since (see above) 1 millimol of O<sub>2</sub> used is associated with the aerobic production of 6.17 millimols of ~P (see above) then the total aerobic production of ~P is M<sub>O<sub>2</sub></sub> \* mols~P / mols O<sub>2</sub>

= 1 millimol \* 6.17 millimols ~P/millimol O<sub>2</sub> = **6.17 millimols ~P**

**Anaerobic:** Starting with glycogen, we get 3 ~P per hexose and two molecules of lactic acid. Put another way, 3/2 = 1.5 mols of ~P are made per mol of lactic acid that accumulates.

Total lactic acid accumulation is the difference between what we started with and finished at -- in this case 11 - 1 = 10 millimols.

Thus, 10 millimols lactate produced \* 1.5 millimols ~P per millimol lactate produced  
**= 15 millimols ~P via anaerobic metabolism**

**Total: anaerobic plus aerobic = 15 + 6.17 = 21.2 millimols of ~P**

***b. What proportion of this animal's exercise was fueled by anaerobic metabolism?***

15 from anaerobic / 21.2 total = **0.71 or 71% -- 2.4X more ~P was generated aerobically than anaerobically**

***c. How many mols of glucose were converted to lactate during the exercise?***

Two lactates are produced per hexose (glucose) derived from the glycogen. Since 10 millimols of lactate accumulated, then **5 millimols of hexose were used**

***d. How many mols of glucose were burned aerobically?***

One mol of glucose is oxidized by per 6 mols of O<sub>2</sub> -- that is, mols of glucose used = 1/6 \* M<sub>O<sub>2</sub></sub>

M<sub>O<sub>2</sub></sub>(mols) = 0.0224 (L O<sub>2</sub>) / 22.4 (L/mol) = 0.001 mols of O<sub>2</sub> used

Mols of hexose used =  $0.001 / 6 = 0.17$  millimols

***Thus, the total hexose used was 5.17 millimols. Notice that  $5/5.17 = 97\%$  of this hexose was used by anaerobic glycolysis even though it accounted for 70% of the ATP production! This is a useful way to lookdemonstation of another effect result of the differences in efficiency between the two processes***